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CTPS TECHNICAL REPORT 39

1981 MBTA FARE-MIX SAMPLING PROGRAM: ANALYSIS AND DOCUMENTATION

GOVERNMENT DOCUMENTS
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JUN 2 1983
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February 1983

CTPS TECHNICAL REPORT 39

TITLE 1981 MBTA Fare-Mix Sampling Program: Analysis and Documentation

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DATE February, 1983

ABSTRACT This report describes the assumptions and methodology used to design and administer a sampling program to determine the fare mix and average fare for rapid transit, buses, and the surface Green Line. The information obtained from this program was used in conjunction with revenue data to determine the number of unlinked and linked trips made on surface and rapid transit in November 1981.

Preparation of this document was financed with funds from the United States Department of Transportation supported with matching state and regional funds.

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EPA Contract #MA-19-0013
UMTA Contract #MA-09-0076
UMTA Contract #MA-09-0084

Production of this document was financed with funds from the UNITED STATES DEPARTMENT of TRANSPORTATION FEDERAL HIGHWAY ADMINISTRATION, through technical study grants from the UNITED STATES DEPT. of TRANSPORTATION URBAN MASS TRANSPORTATION ADMINISTRATION, and with state and local matching funds.

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ACKNOWLEDGMENTS

The following CTPS staff members assisted the MBTA with the design and development of the sampling program and compiled the November 1981 ridership data: Yong Chang, Deborah Schreiber, and Katrina Kalish.

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1.0 INTRODUCTION

Over the years, a number of transit-ridership surveys have been conducted in the Boston region, most of them on behalf of the Massachusetts Bay Transportation Authority (MBTA). They are listed in Table 1-1. Two were quite comprehensive undertakings; the others were more limited in scope, being either mode specific, specific to a certain sector of the region, or specific to a certain type of data.

The most inclusive survey was conducted in 1963 as part of the Boston Regional Planning Project (BRPP), which was a joint effort of the Massachusetts Department of Public Works, the U.S. Department of Commerce--Bureau of Public Roads, and the Housing and Home Finance Agency. Passengers were surveyed onboard vehicles on every mode of public transit, through the distribution of mail-back questionnaires--the postcard survey technique. In addition, carrier-specific information was obtained from each provider of service. The data collected inlcuded daily ridership, characteristics of transit users, i.e., age, occupation, income, auto ownership, mode of access to transit, and frequency of use, trip purpose, trip patterns, travel-density patterns, and service characteristics. This survey cost hundreds of thousands of dollars two decades ago; the cost would be several times that amount today.

The only other recent survey that is somewhat comparable (though not nearly as extensive) was conducted in the spring and fall of 1978. Passenger counts were done on all bus routes and all rapid-transit and trolley lines. Passengers were surveyed, again using the mail-back postcard technique. Daily ridership, transfer patterns, and socioeconomic data were obtained; however, service characteristics were not, and commuter rail was not addressed at all. This survey cost almost one-half million dollars. While such surveys yield a great deal of valuable information, they are far too costly and time consuming to conduct at frequent intervals.

In the absence of regular comprehensive passenger counts, the MBTA has been estimating its ridership. Since revenue is counted daily, it has been possible to estimate daily ridership by dividing revenue by an estimated average fare. In estimating an average fare for this purpose, several factors are considered: modes used (rapid transit, local bus, zoned bus, and express bus); types of riders (full-fare adult, elderly or handicapped, student, and child); methods of fare payment (cash and prepaid pass); and time of travel (by the elderly and handicapped, whose fare varies by time of day).

In August of 1981, the MBTA instituted a new fare policy and, because of the many changes, it was felt that the average fare being used for ridership estimation was no longer entirely valid. Therefore, the Authority decided to develop, in conjunction with CTPS, a new program for estimating ridership in which the average fare used would be determined through surveying a sample of the ridership.

Such a program was put into practice to estimate the ridership levels on the MBTA's surface and rapid-transit systems during November 1981. It was possible to collect sufficient data using the MBTA's regular staff of traffic checkers. Three basic kinds of data were collected at selected rapid-transit stations and on selected surface routes: the number of boarding passengers, the type of fare paid by each, and farebox revenue. The data were processed and analyzed by CTPS.

This report describes the methods and results of the survey and subsequent analysis. With the correction of certain minor problems described in section 3.3, the sampling program enables the MBTA to estimate ridership reliably and relatively inexpensively. The Authority intends to conduct the survey on an annual basis at the minimum.

Type of Count or Survey	Year Conducted or Frequency of Effort	Transit Modes Surveyed	Information Obtained
Postcard survey and carrier survey	1963	•All	•User, service and travel characteristics
Ridership counts	1965	•Rapid transit	•Station boardings
Postcard survey and ridership count	1976	•Commuter rail	•User and travel characteristics
Ridership survey	1977	•Portions of the Red and and Orange lines	•User and travel characteristics
Postcard survey and ridership count	1977	•Portion of the Blue Line	•User and travel characteristics
Postcard survey and ridership count	1977	•North Shore express bus routes	•User and travel characteristics
Postcard survey and ridership count	1978	•Rapid transit lines, trolley lines, bus routes	•User and travel characteristics
Postcard survey and ridership count	1979	•Needham express buses and Framingham commuter-rail line	•User and travel characteristics
Carrier survey and ridership count	1980	•Bus routes assigned to the Arborway Garage	•Service characteristics
Peak-load-point ridership counts	4 times/year	•All bus routes	•Ridership at maximum load point

TABLE 1-1

MBTA TRANSIT SURVEYS

2.0 THE SAMPLING TECHNIQUES

2.1 SURFACE TRANSIT (BUSES, TRACKLESS TROLLEY AND SURFACE GREEN LINE)

Revenue is the basis for estimating ridership using an average fare. Surface transit revenue is collected by garage, and therefore the sampling program was also conducted by garage. Eight surface garages (including the garage for the Green Line) operated 1,176 runs, comprising 7,000 two-way trips over 180 routes, on the average weekday during the fall of 1981.

The fastest and least complicated sampling technique is the simple random sample, wherein each item or individual has an equal chance of being selected. The number of observations or size for this type of sample is determined by the required degree of precision (confidence interval), the allowable degree of risk (confidence level), and the nature of the results required (in this connection, seen in terms of proportions or riders). The formula used to calculate the sample size was $n_o = pq \frac{t^2}{d^2}$,

where n_o = the required sample size
p = the unknown proportion
q = the remaining proportion
d = the interval size
α = confidence level
t = the statistic which relates the confidence level to the normal curve

For the purposes of this survey, the confidence interval was set at ±2.5 percent and the confidence level at 95 percent. These parameters mean that the probability of the estimated average fare mix being within 2.5 percent of the actual average fare mix is one in twenty. The "unknown" and "remaining" proportions correspond, respectively, to the percentage of riders who pay fares other than full adult fare and the percentage who paid full fare. For the purpose of calculating sample size, these proportions were estimated to be fifty/fifty, which produced the largest possible sample size for the given parameters. (Note that of all possible proportions, fifty/fifty is always most conducive to a large sample size.)

The sample size arrived at was 1,540 passengers. Since it was estimated that peak-period trips carry 40 to 50 passengers, 30 to 40 runs had to be sampled in total. This would have

translated into 5 to 7 runs (6 was chosen) per garage if the fare mix were different for each garage. However, in the instances where the mix is the same, the sample would be neither random nor efficient. Therefore, the number of runs to be selected by garage was pro-rated according to the proportion of garage runs to total runs. The resulting number of runs to be sampled per garage ranged from 2 to 12 (see Table 2-1). The bus runs were listed by number and garage, and the selections made using a random-numbers table. See Appendix 3 for runs selected.

Total Saturday bus runs and Sunday bus runs are approximately 50 percent and 20 percent as numerous, respectively, as weekday runs. Therefore, 20 Saturday runs (50 percent of sampled weekday runs) and 8 Sunday runs (20 percent of sampled weekday runs) were sampled.

2.2 RAPID TRANSIT

Since turnstile data provided the necessary information on full-fare riders and prepaid-pass users, only "collector's booths" and gateman's boxes" needed to be sampled. Passengers can pass through gates at these boxes using any fare-payment method. No record is kept of the number of people passing through the gates; however, revenue is counted daily. Gateman's boxes were open daily in 10 stations in November 1981. It was decided that the number of riders using them, by payment category, would be recorded for all 10 stations.

Collector's-booths turnstiles can be passed through without a token or pass card being inserted. In theory, only reduced-fare and no-fare riders use these turnstiles. The number of persons using them is recorded and the revenue counted daily. This permits an average fare calculation; however, no distinction can be made between those paying no fare and those paying reduced fares. It was decided that a random sample of collector's booths would be surveyed and data on type of fare paid and number of riders recorded for both weekdays and weekends.

Since passenger volumes differ considerably from station to station and by time of day, a stratified random sample was considered to be the most logical sampling technique to use for collector's booths. During an average weekday, 13 percent of all rapid-transit users pass through collector's booths at 54 stations. The ratio of passengers through a collector's booth at each station during each of four time periods, to the total number of passengers passing through the booths at all stations during the same time periods, was calculated and listed in a table containing 216 cells on a station-by-station basis. These ratios were then stratified into four groups, three of which accounted for roughly equal percentages of the total. Only a minor proportion of passengers use the gates during the fourth time period.

Garage	Total Weekday Runs	Runs Sampled
Cabot	480	16
Arborway	197	7
Reservoir	163	5
Somerville	128	4
Lynn	102	4
Quincy	84	3
Bennett	22	2
Total	1176	41

Garage	Total Weekend Runs	Runs Sampled
Cabot	357	10
Arborway	152	4
Reservoir	185	7
Somerville	107	3
Lynn	70	2
Quincy	60	2
Bennett	0	-
Total	931	28

RUNS SAMPLED PER GARAGE

TABLE 2-1

It was found that in the first group, 19 cells account for 34 percent of the total; in the second group, 39 cells account for 30 percent of the total; in the third group, 87 cells account for 28.7 percent of the total; and in the fourth group, 71 cells account for 6.3 percent of the total. It was initially determined that at least 1,500 passengers should be sampled from each group. However, it was decided that it would be inefficient to sample the fourth group, and the sample size was increased for each of the other three groups. Therefore, 4, 8, and 17 cells were drawn from the first, second, and third group, respectively (see Table 2-2), for a total sample size estimated at 7600 passengers using the collectors' booth turnstiles.

		6-10a.m.	10-2p.m.	2-6p.m.	6-10p.m.
BLUE	Wonderland	0.2	0.2	0.0	0.0
	Revere	0.3	0.3	--	--
	Beachmont	0.1	0.2	0.0	0.1
	Suffolk Downs	--	0.1	0.3	--
	Orient Heights	[3] 0.4	0.5	0.6	0.0
	Wood Island	0.1	[3] 0.2	0.1	0.1
	Airport	0.0	0.1	0.1	0.1
	Maverick	[2] 0.8	0.6	0.6	0.1
	Aquarium	0.3	0.5	[3] 0.3	--
ORANGE	Oak Grove	0.5	0.1	0.1	--
(N)	Malden	[3] 0.4	0.2	0.1	0.1
	Wellington	0.4	[3] 0.5	0.4	0.0
	Sullivan Square	1.0	0.9	[2] 0.8	0.2
	Community Col.	0.6	0.1	0.1	0.0
(S)	Forest Hills	2.9	1.1	0.8	0.1
	Green	[3] 0.4	0.2	0.1	0.3
	Egleston	1.1	0.5	[3] 0.4	0.2
	Dudley	1.6	[1] 1.7	2.7	--
	Northampton	0.2	[3] 0.5	0.3	--
	Dover	[2] 0.8	1.2	0.6	0.0
	Essex	--	0.5	1.8	0.2

NOTE: Boxed figures are for the time periods/stations chosen for sampling

PERCENTAGE OF TOTAL PERSONS PASSING THROUGH COLLECTOR'S TURNSTILES BY STATION AND TIME PERIOD

TABLE 2-2 p.1

		6-10a.m.	10-2p.m.	2-6p.m.	6-10p.m.
GREEN	Lechmere	0.7	[2] 1.1	0.3	0.1
	Science Park	--	--	--	--
	Kenmore	0.6	0.6	0.7	[3] 0.4
	Auditorium	0.5	0.2	0.6	0.2
	Prudential	0.1	0.1	0.1	--
	Copley	1.3	1.5	[1] 1.6	0.5
	Arlington	0.4	0.7	[2] 0.8	0.1
	Boylston	[3] 0.3	0.5	0.6	0.2
RED	Harvard/Brattle	[1] 1.3	1.1	0.7	0.3
(N)	Harvard	0.7	0.6	0.4	0.1
	Central	0.5	[3] 0.4	0.2	0.4
	Kendall	0.2	0.3	[3] 0.3	0.3
	Charles	0.2	0.5	0.3	0.1
(S)	Braintree	0.3	0.4	0.1	--
	Quincy Ct.	0.8	[2] 1.1	0.3	--
	Wollaston	[2] 0.9	0.6	0.1	--
	No. Quincy	0.8	0.5	0.1	--
	Columbia	0.3	[3] 0.2	0.1	0.3
	Andrew	0.8	0.8	0.5	[3] 0.3
	Broadway	[3] 0.5	0.3	0.4	0.1
	So. Station	0.3	0.5	1.6	0.1

NOTE: Boxed figures are for the time periods/stations chosen for sampling.

PERCENTAGE OF TOTAL PERSONS PASSING THROUGH COLLECTOR'S TURNSTILES BY STATION AND TIME PERIOD

TABLE 2-2 p.2

		6-10a.m.	10-2p.m.	2-6p.m.	6-10p.m.
CBD	State-Orange	0.1	0.7	1.7	0.3
	State-Blue	--	0.5	0.5	--
	Washington-Red	0.3	[2] 1.1	3.2	0.3
	Washington-Org.	0.2	1.2	1.7	0.2
	Government Ct.	0.4	1.4	[1] 2.3	0.3
	Park-Red	0.2	1.5	1.8	0.1
	Park-Green	0.1	0.6	0.7	[3] 0.2
	No. Sta.-Green	0.4	0.4	0.5	--
	No. Sta.-Orange	0.3	0.2	[3] 0.1	--
	Haymarket-Org.	0.3	0.5	0.6	0.1
	Haymarket-Grn.	0.4	0.7	0.4	0.1
		26.3%	31.0%	33.5%	6.6%

NOTE: Boxed figures are for the time periods/stations chosen for sampling.

SOURCE: 1978 MBTA Systemwide Survey

PERCENTAGE OF TOTAL PERSONS PASSING THROUGH COLLECTOR'S TURNSTILES BY STATION AND TIME PERIOD

TABLE 2-2 p.3

3.0 DATA COLLECTION PROCEDURES

As has been explained in chapters 1.0 and 2.0, the three pieces of information that are essential in estimating average fare are the number of boarding passengers, the type of fare paid, and farebox revenue. The procedure for gathering this information differed between surface transit (including the Green Line) and rapid transit.

3.1 SURFACE TRANSIT

- Bus

Because bus runs were used as the basis for data collection, MBTA traffic checkers could stay with a designated driver and cover several routes without having to coordinate the schedules of different routes. Only one checker was needed per bus; he sat behind the driver. He noted the bus route numbers and the time each particular trip began. For each trip made, he recorded the number of persons boarding and the type of fare paid by each. The checkers also recorded the cash and token meter readings from the farebox at the beginning and end of each trip. These counts were conducted from October 31 to November 10, 1981. The bus survey form used is shown in Figure 3-1.

- Green Line

Because the number of boarders was larger on the Green Line than on buses, two checkers were needed for each car on each run: one to record the number of passengers boarding, as the other one called out the types of fare paid. The checkers stayed with the car through the underground portion and made the return trip on the same car. At the point where the car left the portal, the number of persons on the vehicle was recorded as well as the number of persons boarding in the outbound direction. These counts were made November 14 - 17, 1981. However, due to problems, supplemental counts were taken later in the month. The bus survey form was used.

3.2 RAPID TRANSIT

As explained in section 2.2, only collector's booths and gateman's boxes needed to be sampled at the rapid-transit stations, since turnstile data provided the necessary information on full-fare and pre-paid-pass riders. The traffic checkers recorded the number of people passing through the gates by fare payment. They also recorded turnstile readings

FIGURE 3-1

Fare Mix and Ridership Characteristics

Bus Survey Form

Name		Date	1 2 3 4 5
Garage	6 7	Bus #	8 9 10 11
Run #	12 13 14 15	Route #	16 17 18
Direction	○ inbound ○ outbound 19	Start time	○ AM ○ PM 20 21 22 23

Passenger Counting

Adult	Cash fare	24 25 26
	Pass	27 28 29
E & H	Half fare	30 31 32
	Free	33 34 35
Student & Children	Half fare	36 37 38
	Pass	39 40 41
Other free	Authorized	42 43 44
	Not Authorized	45 46 47

Fare Box Reading

Cash	Begin :	48 49 50 51 52	End :	53 54 55 56 57
Penny	Begin :	58 59 60 61 62	End :	63 64 65 66 67
Token	Begin :	68 69 70 71 72	End :	73 74 75 76 77
$ Bills				78 79 80

at the gates and regular turnstiles. These counts were made on November 21 - 24, November 30 and December 1,1981. The rapid-transit survey forms for collector's booths and gateman's boxes, respectively, are shown in figures 3-2 and 3-3.

3.3 PROBLEMS AND PROPOSED SOLUTIONS

Quite a few disabled fareboxes, passmeters, and turnstile meters were encountered during the sampling period. To a certain extent, this problem is unavoidable, since mechanical difficulties and malfunctions can never be totally eliminated. However, in future counts, the problem could be minimized by examining and repairing meters immediately prior to the counting period.

The major problem encountered during the counts occurred on the Green Line. In many instances, the number of people boarding above-ground was not counted. Therefore, additional counts had to be made to ensure a sufficient sample size. Another considerable problem occurred in connection with the counts at the collectors' turnstiles. Some checkers apparently counted people going through the cash gates using passes as well as all people going through the collectors' turnstiles. This problem is related in some degree to the reliability of the revenue collection equipment in that people tend to use the collectors' turnstiles when passmeters and token turnstiles malfunction. This was also the first time that a survey of this type was conducted by the traffic checkers. Performance should improve with experience and more explicit instructions.

FIGURE 3-2

Fare Mix and Ridership Characteristics

Rapid Transit Station Survey Form (Collectors Turnstyle)

Name		Station	
Date		Entrance	
Day of the week		Start Time	○ A.M. ○ P.M.

Passenger Counting

Time Period					
E & H	Half fare				
	Free				
Students & Children	Half fare				
	Pass				
Adults	Cash fare				
	Pass				
Other Free	Authorized				
	Not authorized				

Passenger Reading

Reading	Begin :	End :

Fare Box Reading

Cash	Begin :	End :
Penny	Begin :	End :
Token	Begin :	End :

Remarks

FIGURE 3-3

Fare Mix and Ridership Characteristics

Rapid Transit Station Survey Form (Gate w/ Attendants)

Name		Station	
Date		Entrance	
Day of the Week		Start Time	○ A.M. ○ P.M.

Passenger Counting

Time Period	Prepaid Pass	Full Fare	Other	Total

Passenger Reading if Any

Reading	Begin:	End:

Fare Box Reading

Cash	Begin:	End:
Penny	Begin:	End:
Token	Begin:	End:

Remarks

4.0 ANALYSIS OF DATA--TECHNIQUES AND RESULTS

All survey forms were given to CTPS for coding, data processing, and data analysis. During the coding process, all forms with faulty data were set aside. A computer program was developed to edit the data and calculate revenue, fare mix, and average fare for weekday and weekend travel, by mode and by bus garage.

Note that for the purpose of this survey, an unlinked surface trip is defined as a trip made using only one surface vehicle, and an unlinked rapid-transit trip is defined as a trip made on the rapid transit system (including the underground portion of the Green Line) and can include transfers from one rail-transit line to another.

The following discussions summarize the techniques and results of the data analysis for unlinked trips. A more detailed discussion, including analysis of linked trips, can be found in the appendix.

4.1 RAPID TRANSIT

Rapid transit token and passmeter readings and cash taken in at the various booths are collected and recorded daily. These data are compiled by the MBTA for twelve periods during the calendar year (note that periods are not exactly comparable to months) and published in documents called RTL210 printouts. These data, augmented with sample data from the survey of collector's booths and gateman's boxes and additional revenue data from the MBTA, were used to estimate average fare and ridership on rapid transit. Some adjustments to the total number of tokens used were made because turnstiles at Quincy Center and Braintree require more than one token. Adjustments were also made to passmeter readings because of missing or inaccurate data due to broken meters.

The following estimation results were arrived at for rapid transit on an average weekday:

Fare

Adult	- cash	48.5%
	- pass	29.2
Elderly and Handicapped	- free	11.1
	- ½ fare	3.8

Students and children		5.8%
Free	- authorized	1.2
	- unauthorized	0.4
Average Fare	$.60 cents/trip	
Number of Passenger Trips	305,699	

4.2 SURFACE TRANSIT (SURFACE GREEN LINE, BUSES, AND TRACKLESS TROLLEYS)

The traffic checkers counted passengers and recorded fare mix on the surface portions of the Green Line (excluding the Arborway Branch which was not in service at the time) and on the bus and trackless trolley lines. The following estimated results were obtained from analysis of the sample for the surface Green Line and for bus and trackless trolley:

Surface Green Line

		Weekday	Weekend
Fare mix			
Adult	- cash	38.4%	44.3%
	- pass	25.3	22.9
Elderly and handicapped	- free	5.9	0.4
	- ½ fare	1.6	4.4
Students and children	- pass	0.2	--
	- ½ fare	1.1	1.8
Free	- authorized	27.0	26.2
	- unauthorized	0	0
		100.0%	100.0%
Average Fare*		41.7 cents/trip	48.2 cents/trip

NOTE: The Dorchester Branch and the Mattapan High Speed Trolley Line of the Red Line were closed for track reconstruction and the substitute bus service was not sampled.

*Reflects cash and token revenue only.

Bus and Trackless Trolley

Fare Mix		Weekday		Weekend*
		Bus	Trackless Trolley	
Adult	- cash	38.6%	43.1%	46.5%
	- pass	32.1	43.0	28.4
Elderly and handicapped	- free	7.4	5.7	0.8
	- ½ fare	5.2	5.4	11.7
Students and children	- pass	3.2	--	0.3
	- ½ fare	12.4	2.4	9.2
Free	- authorized	0.6	0.4	2.2
	- unauthorized	0.5	0	0.9
		100.0%	100.0%	100.0%
Average Fare**		40.3 cents/trip		41.5 cents/trip

Weights in accordance with percent of total surface ridership were applied to the Green Line, trackless trolley and bus fare mixes to produce the following composite estimates of fare mix and average fare for surface only, unlinked trips:

Fare Mix		
Adult	- cash	39.6%
	- pass	30.7
Elderly and handicapped	- free	6.3
	- ½ fare	5.3
Students and children	- pass	2.3
	- ½ fare	9.9
Free	- authorized	5.4
	- unauthorized	0.5
		100.0%
Average fare**		41.1 cents/trip

*Trackless Trolley does not operate on weekends
**Cash revenue only

Total surface ridership was then estimated using the data on average fare, surface revenue, and pass use.

Number of Weekday Unlinked Surface Passenger-Trips	422,125

5.0 STATISTICAL ANALYSIS AND COST ESTIMATE

5.1 UTILITY OF THE ESTIMATES

The fare mix and average fare estimated using the survey data are statistically reliable. The estimated average fare mix can be used to estimate system boardings within a confidence interval of ±2.5 percent. If a survey such as the one described in this report is conducted annually, the MBTA will have a valid means of measuring reactions to changes in base fares.

5.2 ACTUAL STATISTICAL CONFIDENCE

The actual calculated confidence intervals at a 95-percent confidence level for the bus system as a whole on weekdays and weekends are presented in Table 5-1. It can be seen that in every case, the intervals are much less than the ±2.5 percent originally proposed; this is a result of the large number of passengers sampled. The weekday confidence intervals for the individual bus garages vary somewhat; they are presented in Table 5-2. Table 5-3 shows that the fare mix varies a great deal from garage to garage: the bus sample should therefore continue to be drawn in the same manner as in the November 1981 sample.

The actual confidence intervals for the gateman's box sample at a 95-percent confidence level are listed in Table 5-4. The actual intervals for the collector's-booth estimates were not calculated because of the problem (described in section 3.) with the estimate of the number of passes used. Note that regular rapid transit turnstiles were not sampled.

5.3 SURVEY COSTS

The estimated cost of conducting the count and processing and analyzing the data is approximately $38,700 ($32,000 data gathering, $6,700 processing and analysis). This is not a large expenditure considering the quality and quantity of the information that was obtained. It should be pointed out that the checkers are already employed by the MBTA and that a large portion of the expenses were charged to a special Capital Planning Program account. (The above costs do not include MBTA management and planning costs.)

	Weekday	Weekend
Adult Cash	±0.90%	±1.22%
Prepaid Pass	±0.86	±1.10
E & H 1/2 Fare	±0.41	±0.79
E & H Free	±0.48	±0.23
Student 1/2 Fare	±0.61	±0.71
Student Pass	±0.33	±0.12
Authorized Free	±0.14	±0.35
Unauthorized Free	±0.13	±0.24

Intervals are calculated using the forumula $\pm \alpha \frac{p_s q_s}{N}$

where α = coefficient of confidence level
p_s = sample proportion
q_s = the remaining proportion
n = number of observations

*95% Confidence Level

ACTUAL CONFIDENCE INTERVALS* - COMPOSITE BUS

TABLE 5-1

	Arborway	Cabot	Salem	Somerville	Lynn	Quincy	Bennett
Adult Cash	±2.28%	±1.51%	±2.34%	±2.80%	±3.95%	±3.15%	±2.66%
Prepaid Pass	±2.21	±1.48	±1.98	±2.77	±3.93	±2.55	±2.67
E & H 1/2 Fare	±1.24	±0.59	±1.13	±1.13	±1.65	±1.81	±1.22
E & H Free	±1.29	±0.78	±1.49	±1.04	±2.97	±2.01	±1.12
Student 1/2 Fare	±1.84	±0.95	±1.96	±1.20	±3.73	±2.38	±0.74
Student Pass	±1.16	±0.75	±0.42	±0.45	±0.54	--	±0.15
Authorized Free	±0.48	±0.22	±0.35	±0.45	--	±0.58	±0.25
Unauthorized Free	±0.53	±0.27	±0.17	±0.22	--	--	--

*95% Confidence Level

ACTUAL CONFIDENCE INTERVALS* - WEEKDAY BY GARAGE

TABLE 5-2

	Arborway	Cabot	Salem	Somerville	Lynn	Quincy	Bennett
Adult Cash	31.80%	37.91%	38.85%	45.11%	29.27%	42.28%	43.46
Prepaid Pass	28.44	34.46	21.70	40.93	28.68	20.08	44.21
E & H 1/2 Fare	6.97	3.73	5.88	4.18	3.74	8.88	5.49
E & H Free	7.59	6.31	10.58	3.55	13.56	11.21	4.58
Student 1/2 Fare	16.99	10.27	21.28	4.81	24.36	16.70	1.96
Student Pass	6.04	6.11	0.78	0.63	0.39	0.00	0.08
Authorized Free	0.99	0.48	0.54	0.63	0.00	0.85	0.22
Unauthorized Free	1.18	0.73	0.12	0.16	0.00	0.00	0.00
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00
AVERAGE FARE	35.0¢	41.0¢	39.4¢	42.7¢	42.9¢	39.0¢	42.1¢

NOTE: Average fare does not include pass revenue.

FARE MIX BY GARAGE

TABLE 5-3

Adult Full Fare	±0.66%
Prepaid Pass	±0.74
Other	±0.82

*95% Confidence Level

ACTUAL CONFIDENCE INTERVAL* - GATEMAN'S BOXES

TABLE 5-4

	Weekday	Weekend
Adult Cash	±1.80%	±2.54%
Prepaid Pass	±1.61	±2.15
E & H 1/2 Fare	±0.87	±0.32
E & H Free	±0.46	±1.05
Student 1/2 Fare	±0.17	--
Student Pass	±0.39	±0.68
Authorized Free	±1.65	±2.25
Unauthorized Free	--	--

*95% Confidence Level

ACTUAL CONFIDENCE INTERVALS* - GREEN LINE

TABLE 5-5

6.0 ALTERNATIVE BUS-RIDERSHIP ESTIMATION TECHNIQUE

There is very little information available on different ridership estimation techniques for rapid transit. However, the present method of making estimates based on meter readings and reported revenue augmented with survey data appears to be highly reliable and inexpensive.

Several means of automatically counting boarding and alighting bus passengers by trip and route are available to the MBTA; these devices do not distinguish types of fare paid. Three of the more tested counters, Infrared Beam Interception, Reflective Infrared Beams, and Treadle Sensor Mats, were evaluated in a 1982 study by Multisystems, Inc.[1]

The first two are essentially variations of one system. The former counter uses two or more light beams which are projected horizontally across the vehicle doorway to a light-sensitive receiver. "When the light beam is interrupted, a count is registered. This information is sent to a counting logic unit which identifies the direction of movement and number of passengers. The sequence in which the beams are broken determines the direction of movement."[2] The second counter also utilizes beams of light projected across the doorway. However, the device that transmits the beams also receives them after they are reflected from the other side of the doorway, thus eliminating the need for two separate devices.

The third system uses "pressure sensitive mats which are installed on the two steps of each door on the bus. The mats contain pressure sensitive elements which are activated when a specified design weight is applied to the treadle. The logic processor is designed to produce a count whenever two steps are sequentially activated and to differentiate between boarding and alighting movements."[3]

None of these systems is problem-free. All generally count boardings more accurately than alightings and tend to undercount both. The equipment can be sensitive to the surrounding environment and requires frequent monitoring and inspection. According to the Multisystems study, "Generally, of the APC (automated passenger counter) units available to a property,

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[1]Multisystems, Inc., Bus Transit Monitoring Study - An Assessment of Automatic Passenger Counters, prepared for U.S. Urban Mass Transportation Administration, June 1982.

[2]Ibid., p. 9

[3]Ibid., p. 10

only 85-90% are in working order at any given time and, of these, only about 80% produce acceptably accurate readings on specific bus runs. Thus, it can be assumed that a typical APC unit installed on a vehicle used for 12 hours a day will on the average obtain the same amount of usable data as a traffic checker assigned for eight hours."[4] Some of the aforementioned problems can be ameliorated through proper installation and a careful monitoring program.

As for the costs of installing and operating the APC systems versus the cost of manual counting, the Multisystems study states that the APCs compare favorably. "The comparison of costs for manual and APC data collection programs indicates that, for most sized properties, APC can be less costly than manual techniques. When costs are accrued over a five year period, the high upfront costs for APC hardware and software development are lower than the on-going costs for manual checker salaries and benefits. The analysis indicates, however, that for those transit properties below 300 peak buses (utilizing less than 7 checkers or APC units), the difference in costs between the two data collection techniques is minimal."[5]

Two other methods of estimating bus ridership are available which provide information on the fare mix. In the first, bus drivers count passengers as they board, recording manually or with automatic counters the number by type of fare paid. Although the drivers might have to be paid an additional fee, no extra personnel would be involved. This could be a less costly way to obtain data on fare mix and ridership; however, it could prove to be more costly in the long-run because of the lower reliability of the information obtained. Drivers are concerned with operating their buses and adhering to schedules; they might not be able or willing to take the time to count all boarders at every stop.

A second and much more sophisticated alternative is the installation of farebox systems that record the number of passengers and the types of fares they pay. At least one model can record magnetic-strip passcard usage. Highly accurate information can be obtained with such systems, but purchase and installation costs are likely to be quite high.

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[4]Ibid., p. 59
[5]Ibid., p. 63

7.0 SUMMARY AND RECOMMENDATIONS

7.1 SUMMARY

The program described in this report produced statistically valid parameters for use in estimating ridership on the MBTA transit system. The program is quick and fairly inexpensive because it uses resources that are readily available to the MBTA.

Since the program has proven to be effective, the basic structure should be maintained. With the correction of certain minor problems described in section 3.3, the program is suitable for annual or even quarterly implementation and thus enables the MBTA to track ridership over a period of time.

Having current information on ridership profiles by fare type is useful for planning and budget purposes. The data provide a base for evaluating impacts on revenue and ridership due to proposed changes in fare policies. The data obtained from this type of survey is also helpful in complying with UMTA Section 15 fare and ridership reporting requirements, specifically form 202 which requests revenue by fare category. The data can also be used to answer surveys received from the American Passenger Transport Association (APTA) as well as various transit authorities around the country.

The data from the program can be used in a number of ways other than estimating ridership. As has been explained, the bus sample is based on bus runs; runs are made up of quite a few one-way trips, many of which are on the same route. Therefore, the sample can supply fare-mix and ridership data by time of day for a large number of routes. Such data can be used to identify routes and garages that serve a high percentage of elderly riders. This can be accomplished by doing a type-of-fare-paid profile on each garage which could be further broken down into routes by garage if there are a representative number of trips on a given route (i.e., Table 5.3 could be calculated for those individual routes where a significant number of trips were surveyed).

The data can also be used to pinpoint routes and garages that may have a significant number of fare evaders. Here again, type-of-fare-paid profiles would be used since there is a category for non-authorized free fare. In addition, those routes which are either under-utilized or are operating at "crush" capacity could be identified, because the raw data include the total number of boardings per surveyed trip.

The program also provides a valuable opportunity to obtain information about the surface portion of the Green Line; data on that part of the system has been particularly sparse.

7.2 RECOMMENDATIONS

The following points should be considered in planning and implementing future surveys. They cover the areas of revenue equipment, survey methods and sample size.

- The mechanical condition of equipment, particularly at rapid transit stations, presented problems during the survey. There should be a regular ongoing maintenance program to ensure that accurate data is obtained throughout the year. Even when such a program is instituted, to ensure the validity of the survey, immediately prior to future counts, passmeters, tokenmeters, cash boxes, and collectors' turnstiles should be inspected and repaired if problems are found to exist.

- The surface Green Line survey would be more efficient if checkers begin outbound trips and end inbound trips at either Kenmore or Prudential stations. In addition, this portion of the survey should be based on trips instead of runs.

- Traffic checkers should be instructed more carefully to avoid the type of counting problems that occurred at the collectors' turnstiles. However, additional experience doing this type of count should help to eliminate the problem.

- Even though the number of people counted this year was much larger than that needed to ensure a statistically valid sample, the sample should be selected in much the same manner for at least one more year (1982) to be certain that the process is indeed working correctly.

DERIVATION OF 1981 RIDERSHIP LEVELS

RAPID TRANSIT UNLINKED TRIPS

Tokens used in Period 11 - 3,118,706[A] (141,759/*average weekday*)

Pass uses -- *passmeter readings from RTL 210 turnstyle data* - 77,044[B]

-- *passholders using gates or collectors turnstyles* - 13,301[C]

Cash gate users + Collectors turnstyle users > 73,595[D]

Pass sales - 49,432[E]

November RTL revenue - $3,932,827[F]

↓

# of unlinked trips/average weekday[G] - 305,699

Fare mix[H]

Uses/pass[I] - 44 *uses/month*

Average fare[J] - 60.0 *cents*

SURFACE UNLINKED TRIPS

Green Line Sample -- *Average fare and fare mix*[K]

Bus Sample -- *Average fare and fare mix*[L]

Period 11 Surface Revenue[F] - $3,656,678

Pass Sales[E] - 58,184

Surface Fare Mix and Average Fare[M]

↓

# of unlinked trips/average weekday[N] - 422,125

Uses/pass[O] - 57 *uses/pass/month*

Average fare[P] - 39.6 *cents*

→ Total Unlinked Trips/Day = 727,824 ←

APPENDIX 1

NOTE: The survey did not include the Dorchester Branch and the Mattapan High Speed Line of the Red Line and the surface portion of the Aborway Branch of the Green Line because they were closed for track reconstruction.

FOOTNOTES TO FLOW CHART

Unlinked Trips - 1981

A. The number of tokens used in Period 11, 1981, was obtained from the MBTA's RTL210 data. This data set is composed of the turnstile readings--both token and passmeter; the cash collected at the collector's booths and cash gates; and the tokens received for each station. The data is recorded daily. For this analysis, the number of "token riders" was used. The number of tokens received at each station is greater than the number of token riders, because some stations require 2 tokens to ride the system.

B. The basic source of the number of pass users who go through a passmeter turnstile was the MBTA's RTL210 data. The total for all stations as reported on the computer printout was not used because of "zero" values at stations where the passmeters were not working. In an effort to obtain a better estimate of passmeter usage, CTPS derived an average weekday value at each station, specifically excluding from the average any days which indicated, either from no entry in the column or an extremely low value, that a passmeter was broken. If there was no passmeter reading for the entire period, the average use at all other stations was applied. This was reviewed to ensure that the stations with missing values were representative of various levels of pass usage. An average value was also obtained for weekend passmeter use in the same manner.

C. The number of prepaid passholders using the gates or collector's turnstiles was estimated from the sampling program conducted at these locations by the MBTA. The proportion of gate users who show prepaid passes was estimated at 15 percent. See Footnote D for a description of the results of the sampling program.

D. The number of passengers entering through the cash gates and collector's turnstiles was estimated as a function of the cash collected at the stations, the average fare paid by collector's turnstile users adjusted for cash gate users, and a factor for pass users. The average fare and fare mix follow:

Average Fare at Collector's Turnstile = 17.5 cents

Average Fare at Cash Gates = 21.7 cents

Weighted Average Fare = 18.5 cents*
(.25 x .217) + (.175 x .75)

Cash Revenue = $13,645/Avg. Weekday

÷ Average Fare = 73,595/Non-Prepaid Pass Users at Cash Gates

WEEKDAY			Avg. Fare
Adult - cash	=	7.5%	x 75
E & H - free	=	52.2%	x 0
- ½ fare	=	15.0%	x 35
Student & Children	=	18.9%	x 35
Free - authorized	=	4.9%	x 0
- unauthorized	=	1.5%	x 0
		100.0%	17.5¢

In addition, 18.1 percent of these cash gate passengers used prepaid passes. There is less certainty about this proportion than the others for a few reasons:

1) The MBTA checkers counted both people going through the cash gates using passes and the collector's turnstile, rather than just those using the collector's turnstile.

2) A large number of passmeters were broken during the sample period, forcing riders who would normally use the regular turnstiles to use the gates. Steps should be taken to address this ongoing problem.

Both of these factors caused the proportion of cash gate riders who use prepaid passes to be overestimated. (The initial proportion

*Numbers presented in this analysis are rounded; 25 percent use cash gates, 75 percent use collector's turnstile.

was 57 percent.) This was adjusted downward by eliminating the prepaid pass users at those stations which had a "zero" or low entry in the passmeter column on the RTL210 printout for the sample day and regular readings for all other days. These pass users would already be counted in the average weekday pass value. Other unreasonably high pass uses (specifically from one checkers count sheets) were eliminated and expected average values were applied.

Prepaid pass holders who use the gates = 13,301 (73,595 x .181)

WEEKEND			Avg. Fare
Adult full cash fare	=	51.1% x	75
E & H - free	=	3.0% x	0
- ½ fare	=	31.4% x	35
Students & Children	=	7.1% x	35
Free - authorized	=	6.0% x	0
- unauthorized	=	1.4% x	0
		100.0%	51.7¢

The additional proportion of pass users is 26.7 percent. The average fare was calculated to be 51.7 cents. Total riders through cash gates are estimated as follows:

$16,677 (cash gate revenue) ÷ .517 (avg. fare) = 32,258 riders

32,258 riders x 0.267 % pass users = 8,613 additional prepaid pass users

E. The distribution between rapid transit and surface passes used in this analysis is shown in the following table. It should be noted that certain passes can be used on both rapid transit and surface, and so some overlap occurs.

DISTRIBUTION OF PASSES

	Total Passes		Proportion Used on Buses/Surface		Proportion on Rapid Transit	
Type of Pass	No.	Revenue	No.	Revenue	No.	Revenue
A	18,794	$ 338,292	18,794 (100%)	$338,292 (100%)	-0-	-0-
B	29,116	$ 786,132	4,000 (13.7%)	$108,000 (13.7%)	25,116 (86.3%)	$ 678,132 (86.3%)
C	4,537	$ 163,332	2,269 (50%)	$ 81,684 (50%)	2,268 (50%)	$ 81,648 (50%)
D	21,233	$ 849,320	19,110 (90%)	$305,760 (36%)	19,110 (90%)	$ 458,640 (54%)
			2,123 (10%)	$ 84,920		$
E	5,722	$ 274,656	4,722 (82.5%)	$184,020 (67%)	3,361 (59%)	$ 90,636 (33%)
F	577	$ 32,312	577 (100%)	$ 16,156 (50%)	577 (100%)	$ 16,156 (50%)
TOTAL	79,979	$2,444,044	51,595	1,118,832	50,432	$1,325,212

Other special methods of fare payment include:

	Number	Revenue
Student Passes (bus only)	6,589	$59,301
Student Tokens (rapid transit only)	116,000	$40,600
Commutation Tickets (express bus and Green Line only)	1,976	$27,664

F. Revenue for Period 11, 1981, was distributed to Surface and Rapid Transit lines as follows:

Surface Revenue			Source
Farebox Revenue/Period	=	$2,565,814/Period	MBTA
Non Farebox Revenue/ Period	=	$1,090,864/Period	
- Prepaid Pass Revenue	=	$1,118,832/Month	MBTA/CTPS - see Footnote E
- Student Pass	=	$ 59,301/Month	MBTA
TOTAL Surface Revenue (non-farebox + farebox revenue)	=	$3,656,678/Period	

Rapid Transit Revenue			Source
Revenue from Tokens Used	=	$2,407,435/Period	RTL210
Cash Gate Revenue	=	$ 298,344/Period*	RTL210
Pass Revenue	=	$1,325,212/Month	MBTA/CTPS
Pass Revenue/Period	=	$1,227,048/Period	
TOTAL Rapid Transit Revenue	=	$3,932,827/Period*	
TOTAL REVENUE	=	$7,589,505*	

The MBTA uses a revenue estimate of $7,839,591. The difference is due primarily to a CTPS adjustment to allocate pass revenue from monthly values to period values.

*The cash gate revenue reported on the RTL210 printouts for Period 11, received by CTPS at the end of December, has since been revised by the MBTA. Cash gate revenue collected during Period 11, 1982, was actually $322,394, thus raising total rapid transit revenue to $3,956,877 and total system revenue to $7,613,555 for Period 11. Due to the manner by which ridership levels were derived, as explained above, this additional cash received does not change the ridership level. Instead it increases the average rapid transit fare to 60.3 cents and the total average fare to 69.9 cents, from 60.0 and 69.7, respectively. The net change in systemwide average fare of 0.2 cents represents a 0.3 percent change. Since this is less than the project's sampling error of $\pm$ 2.5 percent, the figures in this memo have not been revised to reflect the new average. In addition, both levels round to the same average fares of 60 and 70 cents.

G. The number of unlinked rapid transit trips equals 305,699 riders per average weekday.

141,759 = Token trips

90,345 = Prepaid pass users (see Footnote A)

73,595 = Non-pass cash gate users

305,699 = TOTAL

The number of unlinked rapid transit trips/average weekend equals 187,656.

106,319 = Token trips

32,258 = Cash gate users

49,079 = Prepaid pass trips

187,656 = TOTAL *

*Does not include the Dorchester Branch and the Mattapan High Speed Trolley Line.

H. The Fare Mix for unlinked rapid transit trips representing a composite value for an average weekday is as follows:

Adult	- cash	= 48.5%
	- pass	= 29.2%
E & H	- free	= 11.1%
	- ½ fare	= 3.8%
Students & Children		= 5.8%*
Free	- authorized	= 1.2%
	- unauthorized	= 0.4%
TOTAL		= 100.0%

The distribution of riders described in Footnote D referred only to those rapid transit riders passing through the cash gate. The above fare mix includes all rapid transit riders.

*Includes school tokens purchased by the Boston School Department at 35 cents per token.

I. Uses/Prepaid pass = $\frac{\text{Number of pass trips per month (Footnote G)}}{\text{Passes sold for rapid transit per month (Footnote E)}}$

$= \frac{2,146,597}{49,432} = 43.4$ trips/month/pass

$\div 1.08 = 40.2$ trips/period/pass

$\div 21.5 = 1.86$ trips/day/pass

J. The average fare for unlinked rapid transit trips equals:

$$\text{Average fare} = \frac{\text{Rapid transit revenue (Footnote F)}}{\text{Number of rapid transit trips (Footnote G)}}$$

$$= \frac{3,932,827}{6,558,905 \text{ trips/period}}$$

$$= 60.0 \text{ cents/trip}$$

K. The MBTA checkers counted passengers on the surface portions of the Green Line and recorded the fare mix during November 1981. The results are shown below:

FARE MIX		Weekday	Weekend
Adult	- cash	38.4%	44.3%
	- pass	25.3%	22.9%
E & H	- free	5.9%	0.4%
	- ½ fare	1.6%	4.4%
Student & Children	- pass	0.2%	--
	- ½ fare	1.1%	1.8%
Free	- authorized	27.0%	26.2%
	- unauthorized	0%	0%
		100.0%	100.0%
TOTAL AVERAGE FARE* (revenue ÷ number of riders)		41.7 cents	48.2 cents

*Does not include pass revenue.

L. The survey on the bus lines yielded the following distribution of fare payment:

	WEEKDAY		WEEKEND
	Bus	Trackless Trolley	
Adult - cash	38.6%	43.1%	46.5%
- pass	32.1%	43.0%	28.4%
E & H - free	7.4%	5.7%	0.8%
- ½ fare	5.2%	5.4%	11.7%
Student & Children - pass	3.2%	--	0.3%
- ½ fare	12.4%	2.4%	9.2%
Free - authorized	0.6%	0.4%	2.2%
- unauthorized	0.5%	0%	0.9%
AVERAGE FARE	40.3 cents*		41.5 cents

*The 40.3 cent average fare represents the weighted average by bus garage and does not include pass revenue

M. Applying weights in accordance with bus and Green Line ridership--Weekday Bus, 80.3%, Green Line, 17.4%, Trackless Trolley, 2.3%; Weekend Bus, 79.4%, Green Line, 20.6%--yields the following composite fare mix and average fare for surface only, unlinked trips.

Adult	- cash	39.6%
	- pass	30.7%
E & H	- free	6.3%
	- ½ fare	5.3%
Student & Children	- pass	2.3%
	- ½ fare	9.9%
Free	- authorized*	5.4%
	- unauthorized	0.5%
AVERAGE FARE **		41.1 cents

*Includes passengers riding free in the outbound direction on the surface Green Line.

** Does not include pass revenue.

N. The number of unlinked surface trips was derived using the average fare (41.1 cents) and the surface revenue.

Surface non-pass revenue	=	$2,565,814*	
- minus commutation ticket revenue ($27,664)		$2,538,150	
Divided by average non-pass surface fare (41.1)	=	6,175,547	Trips/ Period
Plus 18,296 ticket trips/period (19,760 trips/month)	=	6,193,843	Non-Pass Trips/Period
Divided by .67 (67% of the total trips are non-pass trips)	=	9,244,542	Total Trips/ Period
Divided by 21.9 average weekdays/Period 11 on surface	=	422,125	Total Unlinked Surface Trips/ Weekday

*See Footnote F.

O. The uses/prepaid pass were estimated as follows.

Number of pass trips/period	= 3,050,699 (9,244,542 - 6,193,843)
Divided by 58,184 (# of prepaid passes used on surface vehicles)	= 52.4 Trips/Pass/Period or 2.4 Trips/Pass/Day

P. The average fare for unlinked surface only trips, including passes equals:

TOTAL surface revenue	= $3,656,678
Divided by 9,244,542 trips/period	= 39.6 Cents for Unlinked Surface Trips

Linked Trips

In order to link the rapid transit and surface trips, an estimate of the proportion of rapid transit only, surface only, and combination rapid transit and surface trips is needed. The source used in this analysis is the 1978 Systemwide Survey which included a question about transfer behavior. The proportions for 1978 are expected to have changed due to transit extensions, service cuts, and fare increases instituted since the survey was conducted. For this analysis, the trips were initially linked using the following proportions for November 1981.

	Nov. 1981	Nov. 1980
rapid transit only	31%	29%
combination	39%	40%
surface only	30%	31%

The differences between these numbers result from the service cuts in the Spring of 1981 and the expected impacts of the fare increase of August 1981.

Using the proportions reported above, the rapid transit trips are linked as follows:

rapid transit only	44%	(.31/.70)	134,508
combination	56%	(.39/.70)	171,191
TOTAL	100%		305,699

The bus trips are linked as follows, assuming that surface-to-surface transfers represent 15% of surface-only trips.

surface only	45%	177,945
combination	55%	217,488
	100%	395,433

linked surface-only trips factor:

$$((.45)\ (.15) + (.45) + (.55) + 1.0675$$

linked surface-only trips = 422,125 : 1.0675
= 395,433

Since the number of combination trips differs depending on whether rapid transit or surface unlinked trips are used as a base, an average value has been used for combination trips.

in order to obtain the same number of combination trips from each of the unlinked trip categories (rapid transit and surface), the distribution of trips by mode would be in conflict with that expected from using the '78 Survey as a base. One such possible set of proportions would be as follows:

rapid transit only	134,500	27%
combination	194,300	38%
surface only	177,900	35%
	506,700	100%

The total number of linked trips vary by only 1,000 trips (0.2%) from that estimated using the '78 distribution, although the proportion of trips by mode differ significantly. The former set of numbers is used in this study to be consistent with the '78 Survey.

Using the '78 Survey proportions to link trips, the ridership profile for each mode was developed. Within each mode, the number of pass trips was used as a control total (given that the number of passes bought and the trips/pass are known). The rider profiles and fare mix are shown on the following page.

	%	trips (000's)
rapid transit only	22.3	113.0
combination	38.1	192.7
surface only	39.6	200.0
	100.0	507.7

	Rapid Transit Only		Combination		Surface Only	
	# (000's)	%	# (000's)	%	# (000's)	%
Adult - cash	55.2	(41.0)	90.9	(46.8)	61.7	(34.7)
pass	53.9	(40.1)	49.2	(25.3)	70.1	(39.4)
E & H - ½ fare	4.3	(3.2)	9.5	(4.9)	8.2	(4.6)
- free	12.6	(9.4)	17.9	(9.2)	9.8	(5.5)
Student & Children						
- pass	--	--	--	--	6.2	(3.5)
- ½ fare	6.6	(4.9)	18.8	(9.7)	12.8	(7.2)
Free - authorized	1.5	(1.1)	7.0	(3.6)	8.4	(4.7)
unauthorized	0.4	(0.3)	1.0	(0.5)	0.7	(0.4)
	134.5	(100%)	194.3	(100%)	177.9	(100%)

TOTAL LINKED TRIPS

	# (000's)			%		
Adult - cash	207.8			41.0		
- pass	173.2			34.2		
E & H - ½ fare	22.0	---	62.3	4.3	---	12.3%
free	40.3			8.0		
Student & Children						
- pass	6.2	---	44.4	1.2	---	8.8%
- ½ fare	38.2			7.6		
Free - authorized	16.9	---	19.0	3.3	---	3.7%
unauthorized	2.1			0.4		
	506.7			100%		

The revised average fares for each mode follow:

	%	Cents
Rapid transit only	27%	60.0¢
Combination	38%	98.9¢
Linked surface only*	35%	45.5¢

TOTAL 68.6¢ (1) or 70.3¢ (2)

*Includes surface-to-surface transfers.

(1) Using CTPS's estimate of revenue = $7,589,505 adjusts monthly pass revenue to 4 week revenue and reflects tokens used.

(2) Using MBTA's November 1981 revenue = $7,839,591.

APPENDIX 2

HOW TO USE THE SURVEY FORMS

Attached are completed sample copies of the various survey forms that will be used during the count. Please read all instructions carefully and ask for an explanation of any details that are not clear to you.

1. BUS COUNTS

You will be assigned to a specific run or runs from a given garage. Position yourself behind the driver's seat. Be sure that you have a clear view of all entering passengers and that you can determine the type of fare they pay. Use a separate counting form for each one-way trip and for each:

- Write down your name, the date, the garage name, the bus number, the run number, the route number, the direction of the trip, and the time the trip started.
- Record cash and token readings from the farebox at the beginning and end of each one-way trip.
- For every person boarding the bus, one mark should be made in the box that describes the type of fare paid.

2. GREEN LINE COUNTS

As you can see, the Green Line survey form is identical to the one used for the bus counts, and the same basic information is required. Quite frequently, there are large numbers of boarders at any given stop, particularly during rush hours, therefore, two of you will be assigned to a run.

- On the inbound trip both of you should position yourselves so that you have unobstructed views of boarding passengers and so that you can see clearly the type of fare that is paid.
- Use a separate counting form for each one-way trip and write down your names, the date, the garage name, the car number, the run number, the route number, the direction of the trip and the time the trip started.
- On each inbound trip, also count and record the total number of passengers who are on the vehicle immediately after the vehicle goes underground. Please remember that passengers

must be counted before the first stop underground so that the number of boarders who only use the surface portion of the line can be calculated.

- Stay on the vehicle during the underground portion of the trip and make the return outbound trip on the same car. Count and record the number of passengers onboard immediately after the car leaves the last underground station.

- Count all persons boarding on the surface in the outbound direction and record the numbers in the authorized free category.

3. GATEMAN'S BOXES

Before you start your assignment, fill in your name, the date, the day of the week, the station name, and your starting time on the appropriate form. Record meter readings at the gates. Then, position yourself so that you will not impede the flow of traffic. However, make sure that you can see clearly the number of people passing through the gate as well as the type of fare they pay. Record, by type of fare paid, the number of people passing through on an hourly basis. At the end of your assignment, record all meter readings again.

4. COLLECTORS TURNSTILES

The instructions for counting people who pass through the collectors turnstiles are the same as those for the gatemans' boxes, except there are more fare payment categories. Remember that you only count those going through the collectors turnstiles. Do not count any other passengers. In addition to your duties, please write down token and pass readings for all regular turnstiles at the beginning and end of your shift.

Fare Mix and Ridership Characteristics
Bus Survey Form

Name	Dillon	Date	Friday 1-16-81 (1 2 3 4 5)
Garage	Bennett (6 7)	Bus #	4023 (8 9 10 11)
Run #	1503 (12 13 14 15)	Route #	73 (16 17 18)
Direction	● inbound ○ outbound (19)	Start time	8:14 ● AM ○ PM (20 21 22 23)

Passenger Counting

Adult	Cash fare	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 || (24 25 26)	
	Pass	𝍸 𝍸 𝍸 𝍸 𝍸 || (27 28 29)	
E & H	Half fare	𝍸 𝍸 ||| (30 31 32)	
	Free	(33 34 35)	
Student & Children	Half fare	(36 37 38)	
	Pass	(39 40 41)	
Other free	Authorized	(42 43 44)	
	Not Authorized	(45 46 47)	

Fare Box Reading

Cash	Begin : [illegible]	(48 49 50 51 52)	End : [illegible]	(53 54 55 56 57)	
Penny	Begin : 1336	(58 59 60 61 62)	End : [illegible]	(63 64 65 66 67)	
Token	Begin : 0105	(68 69 70 71 72)	End : 0105	(73 74 75 76 77)	
$ Bills				(78 79 80)	

Fare Mix and Ridership Characteristics

Bus Survey Form

Blandford St. 29

Name	Pecce - Dillon		Date	Friday 12-4-81	1 2 3 4 5
Garage	Boston College	6 7	Bus #	3515	8 9 10 11
Run #	509	12 13 14 15	Route #	311	16 17 18
Direction	● inbound ○ outbound	19	Start time	6:10 ● AM ○ PM	20 21 22 23

Passenger Counting

Adult	Cash fare	𝍸 𝍸 𝍸 IIII	24 25 26
	Pass	𝍸 𝍸 III	27 28 29
E & H	Half fare	II	30 31 32
	Free		33 34 35
Student & Children	Half fare		36 37 38
	Pass		39 40 41
Other free	Authorized		42 43 44
	Not Authorized		45 46 47

Fare Box Reading

Cash	Begin: 45405	48 49 50 51 52	End: 49265		53 54 55 56 57
Penny	Begin: 0031	58 59 60 61 62	End: 0031		63 64 65 66 67
Token	Begin: 9813	68 69 70 71 72	End: 9822		73 74 75 76 77
$ Bills					78 79 80

Fare Mix and Ridership Characteristics
Rapid Transit Station Survey Form (Gate w/ Attendants)

Name	Doolan	Station	North Quincy
Date	11/30/81	Entrance	
Day of the Week	Monday	Start Time	6:00 ● A.M. ○ P.M.

Passenger Counting

Time Period	Prepaid Pass	Full Fare	Other	Total
6:00 AM – 7:00 AM	68	52	38	158
7:00 AM – 8:00 AM	346	224	281	851
8:00 AM – 9:00 AM	155	295	89	539
9:00 AM – 10:00 AM	27	7	40	74
10:00 AM – 11:00 AM	14	0	40	54
11:00 AM – 12:00 PM	3	0	10	13
12:00 PM – 1:00 PM	4	8	42	54
1:00 PM – 2:00 PM	6	7	32	45

Passenger Reading if Any

Reading	Begin: 6:00 AM	End: 6:30 PM

Fare Box Reading

Cash	Begin: 50600	End: 104200
Penny	Begin: 6451	End: 6543
Token	Begin: 5053	End: illegible

Remarks

Fare Mix and Ridership Characteristics
Rapid Transit Station Survey Form (Collectors Turnstyle)

Name	Fitz	Station	Mavericks
Date	11-24-81	Entrance	Main
Day of the week	Tuesday	Start Time	6:00 ● A.M. ○ P.M.

Passenger Counting

Time Period		6-7	7-8	8-9	9-10
E&H	Half fare	7			
	Free		17		69
Students & Children	Half fare				
	Paws				
Adults	Cash fare				
	Pass	16	12	8	
Other Free	Authorized			*10	
	Not authorized				

Passenger Reading

Reading	Begin: 04149	End: 04479

Fare Box Reading

Cash	Begin: 42 975	End: 53110
Penny	Begin: 4540	End: 4570
Token	Begin:	End: 9878

Remarks

Passmeter
Begin 362186
End 363081

P-67
77642 - 87991
77643 - 87998

APPENDIX 3

FARE MIX SURVEY
Bus and Trackless Trolley Survey Schedule

Day of Week	District	Run Number	Date of Count	Comment
Saturday	Cabot	2004	11/7	
		2035	10/31	
		2043	10/31	
		2099	10/31	
		2111	10/31	
	Somerville	2073	11/7	
		2074	11/7	
	Quincy	2029	11/7	
	Lynn	2001	11/7	
	Arborway	2049	10/31	
		2032	10/31	
		2011	10/31	
	Charlestown	2020	11/7	
		2026	11/7	
		2077	11/7	
		2081	11/7	
Sunday	Cabot	3014	11/8	
	Somerville	3003	11/8	
	Quincy	3001	11/8	
	Lynn	3011	11/8	
	Arborway	3401	11/8	
Weekday	Cabot	1022	11/10	
		1052	11/2	
		1060	11/2	
		1107	11/2	
		1809	11/3	
		1819	11/3	
		1528	11/3	
		1313	11/3	
	Bennett (TT)	1803	11/6	
		1904	11/6	
	Somerville	1050	11/6	
		1078	11/6 & 11/10	
		1093	11/10	
		1316	11/6	
	Quincy	1032	11/9	
		1040	11/4	
		1011	11/4	
	Lynn	1038	11/9	
		1050	11/9	
		1311	11/9	
	Arborway	1052	11/4	
		1053	11/4	
		1047	11/4	
		1101	11/4	
		1113	11/4	
	Charlestown	132	11/5	
		322	11/5	
		1045	11/5	
		1049	11/5	
		1415	11/5	

FARE MIX SURVEY

Green Line Survey Schedule

Day of Week	District	Run Number	Date of Count	Comment
Saturday	Reservoir	511	11/14	
		561	11/14	
		540	11/14	
		549	11/14	
Sunday	Reservoir	504	11/15	
		506	11/15	
		563	11/15	
Weekday	Reservoir	902	11/16	
		520	11/17	
		558	11/17	
		569	11/17	
		544	11/16	
		506	11/16	
		509	11/16	

RAPID TRANSIT COUNT
Collectors Turnstile Sample

Weekday (29)

6 AM - 10 AM (9)

Orient Heights
Maverick
Malden
Green
Dover
Boylston
Harvard/Brattle
Wollaston
Broadway

10 AM - 2 PM (9)

Wood Island
Wellington
Dudley
Northampton
Lechmere
Central (INB)
Quincy Ctr
Columbia (South)
Washington N. (Red)

2 PM - 6 PM (8)

Aquarium
Sullivan
Egleston
Copley
Arlington
Kendall
Government Ctr
No. Station (Orange)

6 PM - 10 PM (3)

Kenmore
Andrew
Government Center

NOTE:
If more than one booth is in operation, count should be taken at the booth with the heaviest use.

RAPID TRANSIT COUNT
Collectors Turnstile Sample

Weekend (26)

Saturday (13)		Sunday (13)	
6 AM - 10 AM (5)		6 AM - 10 AM (4)	
	Maverick		Orient Heights
	Dover		Green
	Boylston		Broadway
	Harvard/Brattle		Andrew
	Wollaston		
10 AM - 2 PM (4)		10 AM - 2 PM (5)	
	Wellington		Wood Island
	Dudley		Northampton
	Lechmere		Central (INB)
	Quincy Ctr		Washington No.
2 PM - 6 PM (4)		2 PM - 6 PM (4)	
	Aquarium		Egleston
	Sullivan		Copley
	Arlington		Kendall
	Government Ctr		No. Station (Orange)

Gate - Andrew Station 2:00 PM
to 6:00 PM

NOTE: If more than one booth is in operation, count should be taken at the booth with the heaviest use.

RAPID TRANSIT COUNT
Attendant Gate*

Weekday

North Quincy	6:00 AM - 6:30 PM	12½ hr
Andrew	6:00 AM - 6:30 PM	12½ hr
Forest Hills	6:30 AM - 9:00 AM	2½ hr
	11:00 AM - 4:00 PM	5 hr
Egleston	7:00 AM - 9:30 AM	2½ hr
Dudley	6:30 AM - 9:00 AM	2½ hr
	10:00 AM - 4:00 PM	6 hr
Copley Sq	7:00 AM - 10:00 AM	3 hr
	12:30 PM - 5:30 PM	5 hr

Weekend**

Andrew	Sat - 2:00 PM - 6:00 PM	

*Traffic checkers should also note total passage through turnstile at Collector's Booths during time of Attendant Gate Count.

**Weekend Gate Count should be done on the same weekend as the Collectors Turnstile Counts.

MASS. MP03.2: M45/2/982

CTPS TECHNICAL REPORT 43

1982 MBTA FARE-MIX SAMPLING PROGRAM: ANALYSIS AND DOCUMENTATION

GOVERNMENT DOCUMENTS COLLECTION
SEP 28 1984
University of Massachusetts
Depository Copy

May 1984

CTPS TECHNICAL REPORT 43

TITLE 1982 Fare-Mix Sampling Program: Analysis and Documentation

AUTHOR(S) Alicia Powell Wilson

DATE May 1984

ABSTRACT This report describes the assumptions and methodology used to design and administer a sampling program to determine the fare mix and average fare for rapid transit, buses, and the surface Green Line. The information obtained from this program was used in conjunction with revenue data to determine the number of unlinked and linked trips made on rapid transit and surface routes in November 1982.

This document was prepared by **CENTRAL TRANSPORTATION PLANNING STAFF**, an interagency transportation planning staff created and directed by the Metropolitan Planning Organization, consisting of the member agencies.

Executive Office of Transportation and Construction
Massachusetts Bay Transportation Authority
Massachusetts Department of Public Works
MBTA Advisory Board
Massachusetts Port Authority
Metropolitan Area Planning Council

PREPARED FOR THE BENEFIT AND USE OF THE MUNICIPALITIES CONSTITUTING THE BOSTON METROPOLITAN AREA PLANNING DISTRICT

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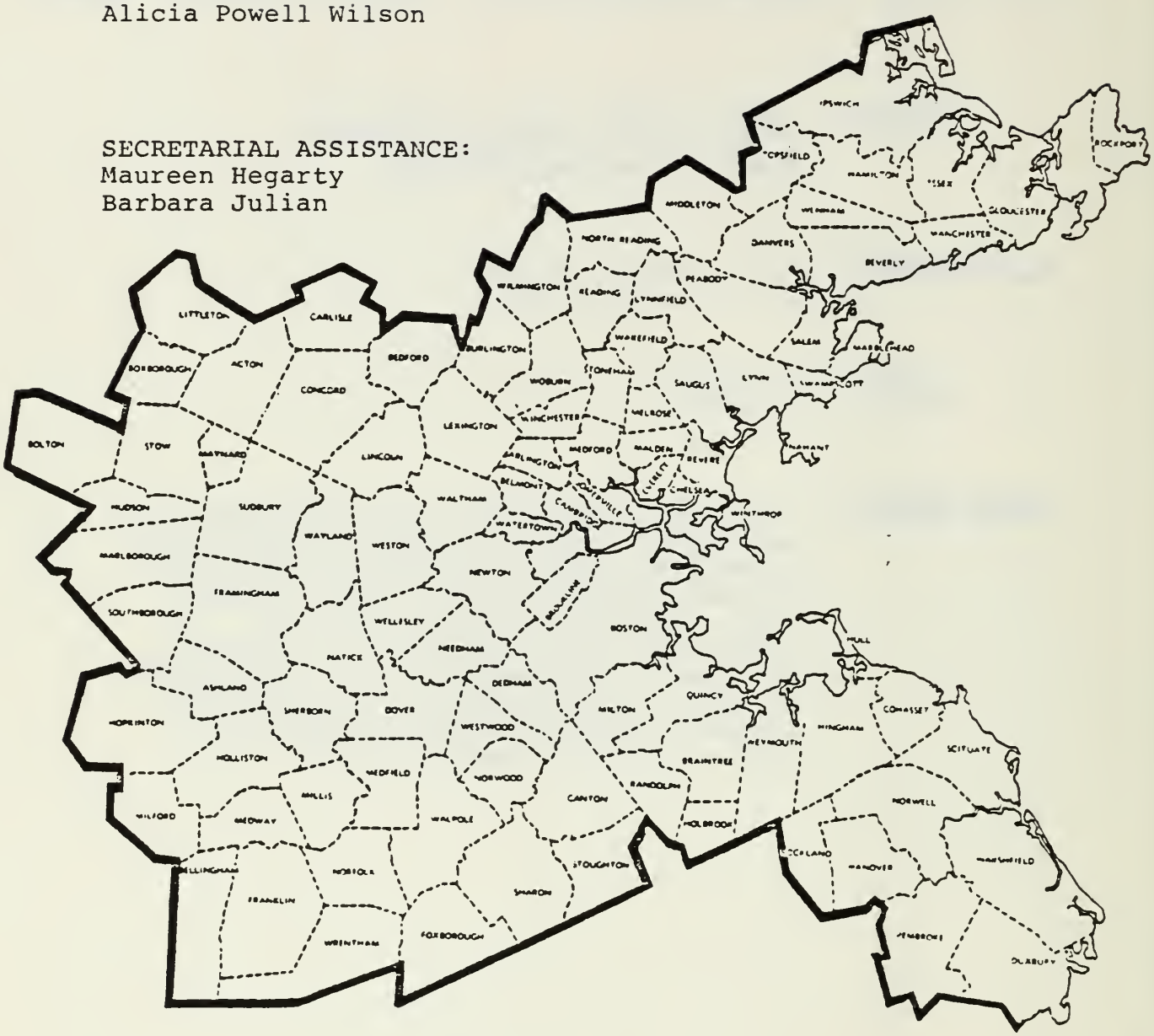

UMTA Grant #MA-09-0095
UMTA Grant #MA-09-0107

Production of this document was financed with funds from the UNITED STATES DEPARTMENT of TRANSPORTATION FEDERAL HIGHWAY ADMINISTRATION, through technical study grants from the UNITED STATES DEPT. of TRANSPORTATION URBAN MASS TRANSPORTATION ADMINISTRATION, and with state and local matching funds.

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ACKNOWLEDGMENTS

Alan Castaline and various other MBTA personnel helped to design and develop the sampling program, and the MBTA traffic checkers collected the data.

1.0 INTRODUCTION

Historically, the MBTA has estimated daily and annual ridership by dividing collected revenue by an average fare. In 1981 it was decided that, because of various fare and system changes, the average-fare figure being used was no longer valid. In addition, accurate data were needed to develop pricing and marketing policies and to satisfy federal reporting requirements.

Therefore, in November of 1981, the MBTA instituted a new program for estimating ridership whereby the average fare used to calculate the number of riders from revenue would be determined by surveying a sample of actual ridership. The number of passengers boarding, the type of fare they paid, and farebox revenue were recorded for selected bus routes, on the surface portions of the Green Line, and at selected rapid transit stations. The resulting data were processed and analyzed by the Central Transportation Planning Staff (CTPS). This program was intended to be implemented annually; therefore the survey was conducted again in November 1982.

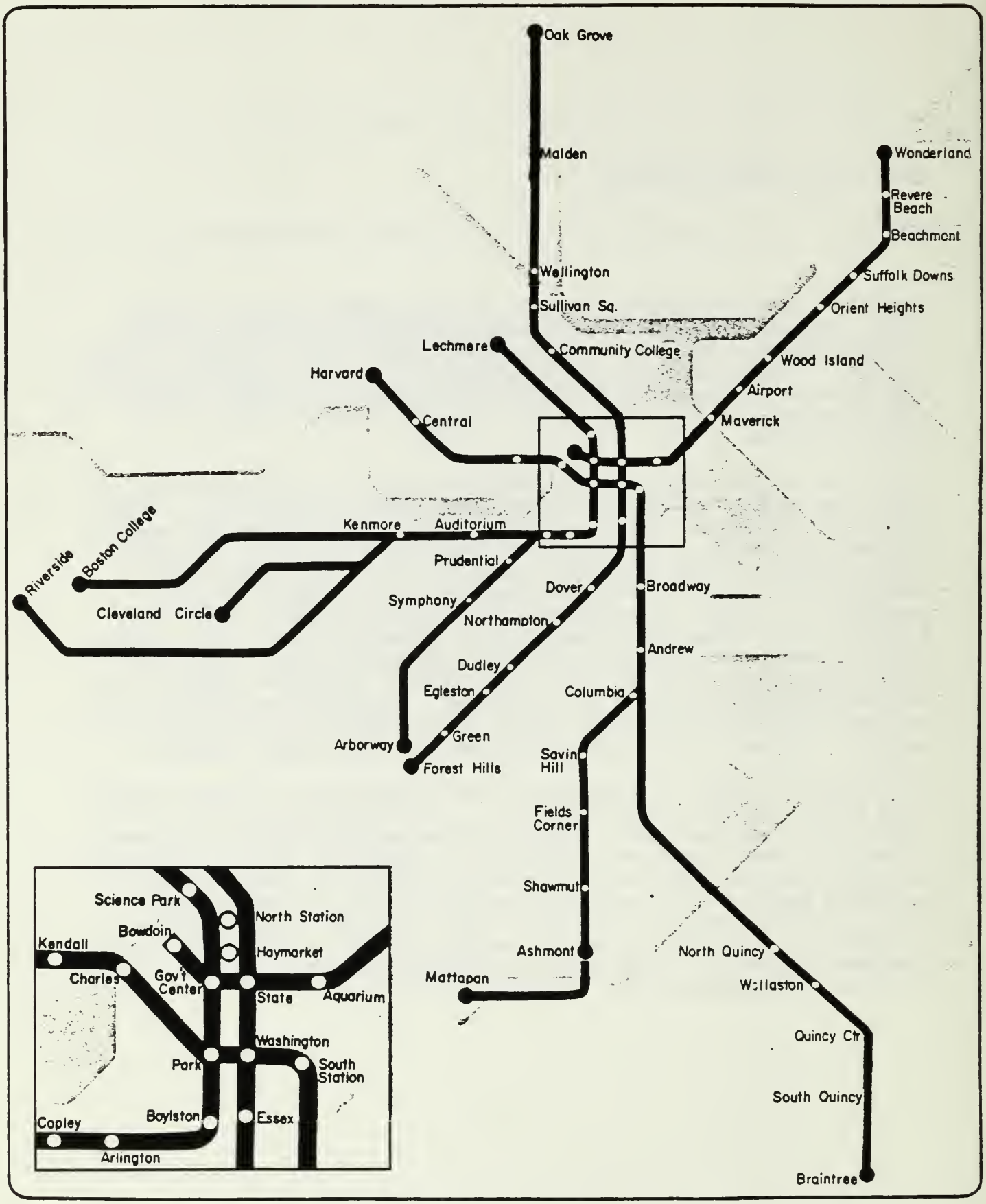
This memorandum documents the results and the analysis of the 1982 survey. Selected 1982 results are also compared with those obtained in 1981.

2.0 MBTA TRANSIT SERVICE

The MBTA operates public transit on four rapid transit lines (Red, Orange, Blue and Green) and on trackless trolley routes, surface bus routes, and commuter rail lines (not covered in this report). The Green Line is a combination of low-platform trolley car service on the surface and rapid transit or subway service in the downtown and Back Bay areas. Figure 2-1 is a map of the transit system.

The basic adult cash fares are sixty cents for rapid transit and fifty cents for trackless trolley and local bus service. There are zoned fares on some local bus routes and a range of fares on express bus routes. Fares on the surface portion of the Green Line are paid in the inbound direction only and range from seventy-five cents to a dollar and a half. Riders can also purchase a variety of monthly pre-paid passes which have no limit on the number of times that they can be used. The elderly (65 and over) and handicapped pay no fare between 9:30 AM and 4:00 PM and half-fare at all other times. Children between five and twelve pay half-fare at all times. Students in grades K-12 pay half-fare during school hours if they have proper identification. Students can also obtain passes from their schools.

All fares are paid as passengers board buses and trolleys and as they enter rapid transit stations. (Passengers also pay an additional fare as they leave Quincy Center and Braintree stations.) In rapid transit stations, tokens are deposited before passengers pass through the regular, full-fare turnstiles. Some turnstiles are also equipped to read electronically the pre-paid passes (not including student passes). Those who pay reduced fares or no fare are supposed to use turnstiles at the collector's booths. "Gatemans' boxes", which allow passengers paying any type of fare to pass through, are open in several stations.



1981 Rapid Transit Network

Figure 2-1

3.0 TRANSIT SERVICE AND FARE CHANGES BETWEEN 1981 and 1982

The user of this data should be cognizant of the fact that apparent increases or decreases in transit ridership between 1981 and 1982 in several categories can, in part, be attributed to transit service changes. In addition, refinements to survey and data analysis techniques have influenced survey results. Attempts have been made in this section and the next to point out these differences and how they affect the data.

3.1 SERVICE CHANGES

In November 1981, the Dorchester Branch of the Red Line (between Columbia and Ashmont stations) and the Mattapan High Speed Line were not in service because new track was being laid. The people who normally used these portions of the system were bused to Andrew or North Quincy stations. The token turnstiles at these stations, particularly Andrew, were not designed to handle the increased passenger load during the AM and PM peaks; therefore, many of those who used tokens and prepaid passes, as well as those who paid cash, went through the collector's turnstiles and the open gates that were monitored by gatemen. This resulted in uncharacteristically high figures for usage of the collector's turnstiles and gateman's boxes. It should also be pointed out that the 1981 sampling program did not allow for surveying those who made local trips on the substitute bus service for the Dorchester Branch.

The Arborway Branch of the Green Line was also not in operation during November 1981. Inbound Arborway users were bused to Copley Station, where they went through gates without paying an additional fare, thereby influencing gate counts at Copley. Service was restored on this branch in June 1982. The addition of Arborway riders in the 1982 sample of the surface Green Line influences the average fare for the Green Line.

3.2 FARE CHANGES

The base rapid transit fare was seventy-five cents in November 1981. It was reduced to sixty cents in May 1982. Student passes were available only for bus trips during 1981. Students who used rapid transit were issued tokens for thirty-five cents apiece. Beginning in September 1982, student passes were available which could be used on either mode. The base fare for surface transit did not change between 1981 and 1982.

4.0 SAMPLING TECHNIQUES AND DATA-COLLECTION PROCEDURES

Ridership is estimated from revenue using an average fare determined from the fare mix. The sampling program was designed to find the fare mix. With the exception of two changes, 1983 sampling techniques are essentially the same as those used in past years. A summary of these techniques is provided below.

The average fare can be calculated as follows:

$$F_a = (F_f \times P_f) + (F_r \times P_r)$$

where F_a = average fare
F_f = full fare
F_r = reduced fare
P_f = % passengers who pay full fare
P_r = % passengers who pay reduced fare

The degree of precision or confidence interval of the average fare can be calculated as follows:

$$\pm (CIP_f \times F_f + CIP_r \times F_r)$$

where CIP = confidence interval of the fare mix (P_f and P_r, respectively)

For the purposes of the sampling program, the confidence interval of the fare mix was set at $\pm$ 2.5 percent and the confidence level (allowable degree of risk) at 95 percent. These parameters mean that the probability of the estimated fare mix being more than $\pm$2.5 percent of the actual fare mix is one in twenty.

To determine the fare mix, the least complicated sampling technique available was the simple random sample wherein each item or individual had an equal chance of being selected. The number of observations or size for this type of sample is determined by the confidence interval, the confidence level, and the nature of the results required (in this connection, seen in terms of proportions of riders). The formula used to calculate the sample size was:

$$No = pq \frac{t^2}{d^2}$$

where no = the required sample size
p = the unknown proportion
q = the remaining proportion
d = the interval size
a = confidence level
t = the statistic which relates the confidence level to the normal curve

The "unknown" and "remaining" proportions correspond, respectively, to the percentage of riders who pay full adult fare and the percentage who pay other than full fare. For the purpose of calculating sample size, these proportions were estimated to be fifty/fifty, which produced the largest possible proportions. (Note that of all possible proportions, fifty/fifty is always most conducive to a large sample size.) Using the given parameters, the formula yields a sample size of 1536, which was rounded to 1540.

After the sampling program was completed, actual confidence intervals obtained were calculated by using the formula

$$\pm \; a\sqrt{\frac{PsQs}{N}}$$

where a = coefficient of confidence level
P^s = sampling proportion
Q^s = the remaining proportion
N = the number of observations

For example, if 1600 passengers were counted and the following data were obtained:

Fare mix - Full fare = 65% (Pf)
Reduced fare = 25% (Pr)
Free = 10%

Fare - Full fare = 60¢
Reduced fare = 30¢

then the confidence interval of the fare mix at a 95% confidence level would be:

$$\underline{\text{Full fare}} = \pm 1.96 \times \sqrt{\frac{.65\ (.35)}{1600}} = \pm 2.34\%$$

or 65% ± 2.34% = 62.66% to 67.34%

$$\underline{\text{Reduced fare}} = \pm 1.96 \times \sqrt{\frac{.25\ (.75)}{1600}} = \pm 2.12\%$$

or 25% ± 2.12% = 22.88% to 27.12%

The average fare would be:

(60¢ x .65) + (.30¢ x .25) = 46.5¢

and the confidence interval of the average fare would be:

(.0234 x .60) + (.0212 x .30) = 2.04¢

or 46.5¢ ± 2.04¢ = 44.5¢ to 48.5¢

4.1 SURFACE TRANSIT (BUSES, TRACKLESS TROLLEY, AND SURFACE GREEN LINE)

Surface-transit revenue is calculated by district; therefore, a sample was drawn from each one. Within a given district, a driver's daily duty assignment is called a "run" which includes trips on one or several routes. It was decided that the bus and trackless trolley sample should be based on runs since the people doing the counts could be assigned to a driver for a day and not have to worry about making connections with other vehicles. Note that the use of runs may not always insure an unbiased estimate for the population as a whole; however, given constraints on time and resources, it is the most efficient method available.

The number of runs sampled per district was pro-rated according to the proportion of district runs to total runs. The resulting number of runs to be sampled per district ranged from 2 to 12 for the weekday sample and from 3 to 5 for the weekend sample. (The total number of runs sampled was determined through estimating the average number of passengers per trip.) All runs were listed by district and the selections were made by using a random-numbers table (see Appendix 2, Table A-26 for the runs selected).

Only one traffic checker per run was needed to collect data for the bus sample. He sat behind the driver and recorded the number of people boarding and the type of fare paid, farebox readings, and other pertinent information (see sample data collection form in Appendix 4).

For the surface Green Line, in 1981, a simple random sample of runs was selected at the Reservoir Garage, from which Green Line cars are dispatched. Traffic checkers were assigned to specific runs, which meant that they had to stay on a particular car until their shifts ended. They counted people boarding inbound on the surface portion, recorded the type of fare paid, and recorded surface revenue; then they rode underground to the end of the line, rode back in the outbound direction, and counted people boarding outbound on the surface. Among the problems encountered were frequent farebox malfunctions, which meant that sometimes there was no revenue figure (and therefore no average fare) for an entire run. The procedure was confusing to the checkers and they frequently failed to count those boarding in the outbound direction; and, even though a portion of the survey was conducted a second time, some faulty data was still obtained.

In 1982, it was decided that the sample of the surface Green Line should be based on trips instead of runs. The 1978 systemwide survey was used to determine the minimum number of inbound trips that had to be surveyed per time period, by branch (see Table 4-1). The same number of outbound trips per period also had to be surveyed. The first AM inbound trip to be boarded by a given checker on a given survey day was selected randomly (from trips before 6:05 AM). The checker rode in on that trip, got

% INBOUND SURFACE GREEN LINE BOARDERS BY TIME PERIOD*

	RIVERSIDE	BOSTON COLLEGE	CLEVELAND CIRCLE
6:00-9:00 A.M.	36.0%	27.2%	35.8%
9:00-3:00 P.M.	36.1	46.6	42.0
3:00-6:00 P.M.	21.3	20.5	16.5
6:00-midnight	6.6	5.7	5.8
Total	100.0	100.0	100.1

MINIMUM INBOUND TRIPS TO BE SURVEYED PER PERIOD**

	RIVERSIDE	BOSTON COLLEGE	CLEVELAND CIRCLE	ARBORWAY
6:00-9:00 A.M.	4	3	3	2
9:00-3:00 P.M.	4	6	4	4
3:00-6:00 P.M.	2	2	1	2
6:00-midnight	1	1	1	1
Total	11	12	9	9

*SOURCE: 1978 Systemwide Survey

**Arborway was not surveyed with the Green Line-surface in 1978; however, it was felt that the Arborway ridership profile closely resembles that of the Cleveland Circle Branch.

off at Kenmore (Symphony on the Arborway branch), and got on the next outbound car on the branch to which he had been assigned. Therefore, if a car had a faulty farebox meter, only one rather than a series of surveyed trips had unusable data. The 1982 outbound count was much more accurate than that of 1981. The data show an increase in outbound ridership; however, the actual increase is probably not as large as it appears to be.

4.2 RAPID TRANSIT

At rapid transit stations, only collector's booth turnstiles and gateman's boxes required manual counting, since the regular turnstiles, when functioning properly, provide the necessary data on token and prepaid pass usage. Traffic checkers recorded the number of people passing the gateman's box by method of fare payment. They recorded turnstile readings at the collector's booth turnstiles (and at the regular turnstiles, as a back-up to the data provided by the MBTA).

During an average weekday, 13 percent of all rapid-transit users pass through collector's booth turnstiles at 54 stations. The ratio of passengers passing through a collector's booth turnstile at each station during each of four time periods, to the total number of passengers passing through the booth turnstiles at all stations during the same time periods, was calculated and listed in a table containing 216 cells on a station-by-time-period basis. These ratios were then divided into four groups, three of which accounted for roughly equal percentages of the total. Only a minor proportion of passengers were accounted for in the fourth group; therefore, it was decided that it would be inefficient to sample that group. It was initially determined that 1500 passengers should be sampled from each group, but, when the fourth group was eliminated the sample size was increased for each of the other groups and cells were drawn from the first, second, and third group equally.

In 1982, as in 1981, only a limited number of rapid transit stations had gateman's boxes that were authorized to be open, so all of these were sampled. However, it was discovered that gates at many stations were open unofficially. Therefore, a random sample was selected for counts at unofficial gates -- i.e., gates without boxes (see Appendix 2, Table A-2).

5.0 ANALYSIS OF DATA

The following discussion summarizes the data analysis for unlinked and linked trips. A more detailed explanation, can be found in Appendix 1.

For the purpose of this survey, an unlinked surface trip is defined as a trip made using one surface vehicle, and an unlinked rapid transit trip is defined as a trip made on the rapid transit system (including the underground portion of the Green Line) and can include transfers from one rail transit line to another. A linked trip is defined as one trip from origin to destination and can include several transfers.

5.1 UNLINKED TRIPS

5.1.1 Rapid Transit

Rapid transit token and passmeter readings and cash taken in at the various booths are recorded daily by the MBTA. These data, augmented with sample data from the survey of collector's turnstiles and gateman's boxes and additional revenue data from the MBTA, were used to estimate average fare and unlinked rapid transit trips. Some adjustments to the data on tokens were made because turnstiles at Quincy Center and Braintree require more than one token. Adjustments were also made to passmeter readings for missing or inaccurate data due to broken meters. Estimated pass usage by rapid transit line for 1982 is presented in Appendix 3.

The estimated fare mix, average fare, and number of unlinked trips are presented in Table 5-1. The number of unlinked rapid transit trips increased by 9.8% between 1981 and 1982. The 1981 average fare was 60¢ per unlinked trip, while the average fare for 1982 was 50.4¢ per trip. Major reasons for the decrease in average fare are the reduction in the price of a token from 75¢ in 1981 to 60¢ in 1982, the availability of rapid transit student passes in 1982, and an increase in the use of adult and surface transit student passes.

5.1.2 Surface Transit (Surface Green Line, Buses, and Trackless Trolleys)

The traffic checkers counted passengers and recorded fare mix on the surface portions of the Green Line and on selected bus and trackless trolley routes. The analyzed results are shown in Tables 5-2 through 5-5.

		1981	1982
Fare			
Adult	- Cash	48.5%	49.9%
	- Pass	29.2%	32.3%
Elderly & Handicapped	- Free	11.1%	8.9%
	- 1/2 Fare	3.8%	3.2%
Student & Children	- 1/2 Fare	5.8%	1.9%
	- Pass	--	2.9%
Free	- Authorized	1.2%	0.8%
	- Unauthorized	0.4%	0.2%
		100.0%	100.0%
Average Fare/Trip		60.0¢	50.4¢
Total Unlinked Trips		305,000	335,581

RAPID TRANSIT FARE MIX 1981 AND 1982

TABLE 5-1

Fare Mix		Weekday	Weekend
Adult	- Cash	29.6%	41.6%
	- Pass	27.4%	21.1%
Elderly & Handicapped	- Free	3.6%	--
	- 1/2 Fare	0.9%	4.4%
Students & Children	- Pass	0.1%	--
	- 1/2 Fare	1.5%	1.3%
Free	- Authorized	36.9%	31.4%
	- Unauthorized	--	0.2%
		100.0%	100.0%
Average Fare*		33.7¢	45.7¢
Confidence Interval of Average Fare		±1.0¢	±1.2¢

*Does not reflect pass revenue.

1982 SURFACE GREEN LINE FARE MIX

TABLE 5-2

Fare Mix		Weekday Bus	Weekday Trackless Trolley	Weekend Bus
Adult	- Cash	35.4%	31.3%	39.6%
	- Pass	33.9%	45.1%	37.0%
Elderly & Handicapped	- Free	11.9%	12.5%	--
	- 1/2 Fare	4.1%	0.7%	14.6%
Students & Children	- Pass	4.1%	5.0%	--
	- 1/2 Fare	9.6%	5.4%	7.1%
Free	- Authorized	1.0%	0.0%	1.5%
	- Unauthorized	0.0%	0.0%	0.2%
		100.0%	100.0%	100.0%
Average Fare**		36.3¢		41.9¢
Confidence Interval of Average Fare		±.6¢		±.8¢

*Trackless trolley does not operate on weekends.
**Does not reflect pass revenue.

1982 Bus And Trackless Trolley Fare Mix

TABLE 5-3

	Arborway		Cabot[1]		Salem[2]		Somerville[3]		Lynn		Quincy		Bennett	
	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982	1981	1982
Adult Cash	31.80%	33.3%	37.91%	32.9%	38.85%	37.6%	45.11%	37.6%	29.27%	40.1%	42.28%	36.0%	43.46%	31.3%
Prepaid Pass	28.44%	34.3%	34.46%	40.9%	21.70%	32.1%	40.93%	34.9%	28.68%	18.6%	20.08%	21.7%	44.21%	45.1%
E & H Half Fare	6.97%	2.5%	3.37%	3.5%	5.88%	8.1%	4.18%	3.3%	3.74%	4.5%	8.88%	3.9%	5.49%	0.7%
E & H Free	7.59%	13.8%	6.31%	11.1%	10.58%	6.2%	3.55%	12.8%	13.56%	19.2%	11.21%	10.7%	4.58%	12.5%
Student and Children Half Fare	16.99%	10.6%	10.27%	7.5%	21.28%	11.4%	4.81%	9.2%	24.36%	9.7%	16.70%	14.8%	1.96%	5.4%
Student Pass	6.04%	5.2%	6.11%	3.2%	0.78%	4.5%	0.63%	1.5%	0.39%	4.3%	0	11.3%	0.08%	5.0%
Authorized Free	0.99%	.3%	0.48%	0.9%	0.54%	0.1%	0.63%	.7%	0	3.5%	0.85%	1.6%	0.22%	0
Unauthorized Free	1.18%	0	0.73%	0	0.12%	0	0.16%	0	0	0	0	--	0	0
TOTAL	100.00%	100.0%	100.00%	100.0%	100.00%	100.0%	100.00%	100.0%	100.00%	100.0%	100.00%	100.0%	100.00%	100.0%
Average Fare	35.0¢	32.6¢	41.0¢	38.2¢	39.4¢	37.2¢	42.7¢	36.0¢	42.9¢	37.1¢	39.0¢	34.0¢	42.1¢	35.4¢
Actual Confidence Interval		±1.2¢		±.9¢		±1.4¢		±1.2¢		±1.8¢		±2.0¢		±1.5¢

[1] Includes Albany Garage
[2] Includes Fellsway Garage
[3] Includes Charlestown

TABLE 5-4

1981 AND 1982 WEEKDAY FARE MIX AND AVERAGE FARE BY BUS GARAGE

Fare Mix		1981	1982
Adult	- Cash	36.9%	34.9%
	- Pass	30.7%	32.6%
Elderly & Handicapped	- Free	6.3%	8.9%
	- 1/2 Fare	5.3%	4.3%
Student & Children	- Pass	2.3%	2.9%
	- 1/2 Fare	9.9%	7.4%
Free	- Authorized	5.4%	9.0%
	- Unauthorized	0.5%	--
		100.0%	
Average Fare*		41.1¢	36.7¢

*Does not reflect pass revenue.

TOTAL WEIGHTED SURFACE FARE MIX, 1981 AND 1982

TABLE 5-5

Table 5-4 shows 1981 and 1982 fare mix and average fare by bus garage. Pass usage increased for all but two garages, as did the proportion of elderly and handicapped passengers who paid no fare. In the latter case, several garages had rather substantial increases. Even though the base fare did not change between 1981 and 1982, 1982 average fare is lower than 1981 average fare because of the increase in the number of those who pay no cash fare (including pass users and authorized free riders, although the increase in the latter is partially a result of sampling techniques). Estimated pass usage by garage for 1982 is presented in Appendix 3.

Weights in accordance with percent of total surface ridership were applied to the Green Line, trackless trolley, and bus fare mixes to produce the composite estimates of fare mix and average fare for surface-only unlinked trips presented in Table 5-5. The corresponding data for 1981 are provided for comparison.

5.2 LINKED TRIPS

In order to link rapid transit and surface trips, an estimate of the proportion of rapid-transit-only, surface-only, and combination (rapid transit and surface) trips is needed. For this year's analysis, as for last year's, the source used was the 1978 Systemwide Survey, which included a question about transfer behavior. Because of service cuts, fare increases, and transit line extensions instituted after that survey was taken, 1981 proportions were changed slightly to 31% rapid-transit-only, 30% surface-only, and 39% combination. By November 1982, however, much of the cut service had been restored and rapid transit and pass fares had been reduced. Therefore, the 1978 proportions of 29%, 31%, and 40%, respectively, were thought to be more appropriate.

The actual process for linking trips for 1982 was not the same as that used in 1981 because it was felt that the accuracy of the 1981 process could be improved by assuming that the proportion of combination trips is more accurate than the individual surface-only and rapid-transit-only proportions. Simultaneous equations were used to find the total number of combination trips, which were then subtracted from total unlinked rapid transit trips and total unlinked surface trips to find rapid-transit-only and surface-only trips.

The 1981 trips were re-linked using this new method so that the results could be compared with those for 1982. The new results for 1981 are 490,900 average weekday linked trips and an average fare of $.711. The 1982 results are 540,547 average weekday linked trips (an increase of 10.3%) and an average fare of $.603 (a decrease of 15.2%).

The calculations for 1982 are summarized in Appendix 1.

6.0 STATISTICAL ANALYSIS AND COST ESTIMATE

The estimated average fare mix can be used to estimate boardings within a confidence interval of ±2.5%.

The actual confidence intervals at a 95% confidence level for the bus system, the Green Line, collector's turnstiles, and gateman's boxes are presented on the following pages. Note that in almost all instances the intervals are much less than the ±2.5% proposed in the sample design.

The estimated cost of conducting the count was approximately $31,000, while the preparation, processing, and analysis of data cost approximately $31,000.

	Weekday	Weekend
Adult Cash	±0.74%	±1.13%
Adult Pass	±0.68%	±1.12%
E & H 1/2 Fare	±0.30%	±0.82%
E & H Free	±0.51%	--
Student & Children 1/2 Fare	±0.45%	±0.60%
Student Pass	±0.31%	--
Authorized Free	±0.15%	±0.28%
Unauthorized Free	--	±0.09%

ACTUAL CONFIDENCE INTERVALS* - COMPOSITE BUS

TABLE 6-1

	Arborway	Cabot	Salem	Somerville	Lynn	Quincy	Bennett
Adult Cash	±1.91%	±1.28%	±2.10%	±1.90%	±2.53%	±2.77%	±2.63%
Adult Pass	±1.93%	±1.34%	±2.02%	±1.87%	±2.01%	±2.38%	±2.83%
E & H 1/2 Fare	±0.64%	±0.50%	±1.18%	±0.71%	±1.07%	±1.12%	±0.46%
E & H Free	±1.40%	±0.86%	±1.04%	±1.31%	±2.04%	±1.78%	±1.88%
Student & Children 1/2 Fare	±1.25%	±0.72%	±1.38%	±1.14%	±1.53%	±2.05%	±1.28%
Student Pass	±0.90%	±0.48%	±0.90%	±0.48%	±1.05%	±1.83%	±0.15%
Authorized Free	±0.24%	±0.26%	±0.14%	±0.32%	±0.95%	±0.74%	--
Unauthorized Free	--	--	--	--	--	--	--

ACTUAL CONFIDENCE INTERVALS* - WEEKDAY BY BUS GARAGE

TABLE 6-2

	Arborway	Cabot	Salem	Somer.	Lynn	Quincy	Bennett	Total
Adult Cash	775	1704	770	934	577	415	372	5547
Adult Pass	799	2120	658	866	268	250	537	5498
E & H 1/2 Fare	59	181	165	83	65	45	8	606
E & H Free	322	576	126	317	276	123	149	1889
Student & Children 1/2 Fare	246	388	234	229	140	171	64	1472
Student Pass	120	166	92	37	62	130	60	667
Authorized Free	8	48	2	17	50	19	0	144
Unauthorized Free	0	0	0	0	0	0	0	0
Total	2329	5183	2047	2483	1438	1153	1190	15,823

TABLE 6-3

ABSOLUTE NUMBER COUNTED BY GARAGE AND FARE-TYPE

	Absolute # Counted	Weekday	Absolute # Counted	Weekend
Adult Cash	1948	±1.10%	2528	±1.24%
Prepaid Pass	1803	±1.08%	1281	±1.03%
E & H 1/2 Fare	62	±0.23%	265	±0.51%
E & H Free	237	±0.45%	--	--**
Student & Children 1/2 Fare	96	±0.29%	81	±0.29%
Student Pass	10	±0.09%	--	--
Authorized Free	2430	±1.17%	1912	±1.17%
Unauthorized Free	--	--	11	±0.11%
	6586		6078	

*95% confidence level
**Reflected in "Unauthorized Free"

ACTUAL CONFIDENCE INTERVALS* - GREEN LINE

TABLE 6-4

	Absolute # Counted	Weekday	Absolute # Counted	Weekend
Adult Cash	540	±0.80	692	±1.74
Adult Pass	663	±0.88	714	±1.76
E & H 1/2 Fare	756	±0.93	787	±1.81
E & H Free	2072	±1.30	--	--
Students & Children 1/2 Fare	439	±0.73	178	±1.0
Students & Children Pass	674	±0.89	--	--
Authorized Free	179	±0.48	50	±.78
Unauthorized Free	49	±0.25	104	±.78
	5372		2525	

*95% confidence level

ACTUAL CONFIDENCE INTERVALS* - COLLECTOR'S TURNSTILES

TABLE 6-5

7.0 SUMMARY AND RECOMMENDATIONS

7.1 SUMMARY

Analysis of November 1982 ridership indicates that the number of linked trips increased by 10.3% to 540,547 trips, from 490,000 in November 1981. The average fare decreased by 15.2%, from 71.1¢ to 60.3¢. (These 1981 figures are for 1981 trips linked according to the procedure that has been used for 1982 trips, which differs from the procedure that was used for 1981 trips in the CTPS Technical Report 39, as discussed in Section 5.2 of this report.) Part of the decrease in the average fare can be attributed to the decrease in the base rapid transit fare from 75¢ to 60¢. Another contributing factor is an increase in pass usage, which was partly a result of student rapid transit passes being made available.

7.2 RECOMMENDATIONS

The following points should be taken into consideration in planning and implementing all future surveys.

- The mechanical condition of transit-system data-collection devices continues to be a problem, during the implementation of a survey in particular, as well as at other times. There should be an ongoing program of regular maintenance to ensure that accurate data is obtained throughout the year, particularly at rapid transit stations.

- The number of people counted was much larger than the number needed to ensure statistical validity, particularly on the surface lines. If an overall bus fare mix is the aim rather than the mix by individual garages, the sample can be reduced quite substantially without affecting the validity of the results (see Table 7-1). Even if fare mix is desired by garage, the sample size could still be reduced significantly. One could look at the number counted for each garage and reduce the number of runs sampled accordingly. The same procedure could be followed for the surface Green Line count.

	Full Sample	1/2 Sample	1/4 Sample
Adult Cash	35.1%	34.8%	35.5%
Adult Pass	34.7	33.7	35.2
E & H Free	11.9	12.4	11.7
E & H 1/2 Fare	3.8	4.1	3.0
Student & Children 1/2 Fare	9.3	10.2	9.4
Student Pass	4.2	3.7	4.4
Authorized Free	0.9	1.0	0.9
Unauthorized	--	--	--
	100.0%	100.0%	100.0%
Average Fare*	36.3¢	36.5¢	36.9¢
Sample Size	15,823	7,477	4,294

*Does not reflect pass revenue

AVERAGE FARE MIX BUS AND TRACKLESS TROLLEY

TABLE 7-1

APPENDIX 1

Annotated Flow Chart

of

1982 Fare-Mix and Ridership Derivation

DERIVATION OF 1982 FARE-MIX AND RIDERSHIP

Part I

Rapid Transit/ Unlinked Trips

Tokens used in Period 11 - 3,376,144[A] (155,255/avg. weekday)

Pass uses -- passmeter readings from RTL210 turnstile data - 87,647[B]

-- passholders using gates or collector's turnstiles - 22,581[C]

Cash-gate users 70,128[D]

Collector's turnstile users

Pass sales - 56,715[E]

Period 11 RTL revenue - $3,636,496[F]

# of unlinked trips/average weekday - 335,581[G]

Fare mix[H]

Uses/pass - 41.6 uses/period[I]

Average fare - 50.4 cents[J]

Part II

Surface Transit/ Unlinked Trips

Green Line sample - average fare and fare mix[K]

Bus Sample - average fare and fare mix[L]

Period II surface revenue - $3,451,370[F]

Pass sales - 52,359[E]

Surface fare mix and average fare[M]

# of unlinked trips/average weekday - 471,824[N]

Uses/pass - 62.7 uses/pass/period[O]

Average fare - 33.6 cents[P]

Total Unlinked Trips/Weekday = 807,405

Part III

Linked Trips/Average Fare

Linked Trips/Weekday = 540,547[Q]

Average Fare = $.603[Q]

NOTE: See notes A through Q on the following pages.

NOTES TO FLOW CHART

Part I - Rapid Transit/Unlinked Trips

A. The number of tokens used in Period 11, 1982, was obtained from the MBTA's RTL210 data. This data set is composed of the turnstile readings--both token and passmeter; the cash collected at the collectors' booths and gateman's boxes; and the tokens received for each station. The data is recorded daily. For this analysis, the number of "token riders" was used. The number of tokens received at each station is greater than the number of token riders, because boarding at some stations requires two tokens.

B. The basic source of the number of pass users who go through a passmeter turnstile was the MBTA's RTL210 data. The total for all stations as reported on the commuter printout was not used because of "zero" values at stations where the passmeters were not working. In an effort to obtain a better estimate of passmeter usage, CTPS derived an average weekday value at each station, specifically excluding from the average any days which indicated, either from no entry in the column or an extremely low value, that a passmeter was broken. If there was no passmeter reading for the entire period, the average use at all other stations was applied. This was reviewed to ensure that the values derived for the stations with missing values were representative of various levels of pass usage. An average value was also obtained for weekend use in the same manner.

C. The number of prepaid passholders using the gates or collectors' turnstiles was estimated from the sampling program conducted at these locations by the MBTA. The proportion of gate users who show prepaid passes was estimated at 32.2% of all users. See Note D for a description of the results of the sampling program.

D. The number of passengers entering through the cash gates and collectors' turnstiles was estimated as a function of the cash collected at the stations, the average fare paid by collectors' turnstile users adjusted for cash-gate users, and a factor for pass users. The average fare and fare mix follows:

Average Fare at Collectors' Turnstiles = 18.9 cents

Average Fare at Cash Gates = 31.0 cents

Weighted Average Fare = 20.8 cents

(.841)(.189) + (.159 x .31)

Cash Revenue = $14,586.67/Avg. Weekday

÷ Average Fare = 70,128/Non-Prepaid Pass Users at Cash Gates

FARE MIX AT COLLECTORS' TURNSTILES

		Weekday		Weekend	
		1981	1982	1981	1982
Adult	- cash	7.5%	12.1%	51.1%	38.2%
E & H	- free	52.2%	50.5%	3.0%	
	- 1/2 fare	15.0%	21.0%	31.4%	43.4%
Student & Children	- 1/2 fare	18.9%	10.9%	7.1%	9.8%
Free	- authorized	4.9%	4.2%	6.0%	2.8%
	- unauthorized	1.5%	1.3%	1.4%	5.7%
Average Fare*		17.5¢	18.9¢	51.7¢	39.3¢

*Does not include pass users.

The weekend average fare was calculated to be 39.3 cents, resulting in a non-prepaid ridership of 48,089 (revenue = $18,898.95).

In addition, 32.2% of weekday and 39.4% of weekend cash gate passengers used prepaid passes (22,581 pass users go through cash gates on the average weekday, 18,947 go through on the average weekend).

(Note that in 1982, the average fare was calculated directly from survey data. In 1981, the expected average fare was used.)

E. The distribution between rapid transit and surface passes used in this analysis is shown in the following table. It should be noted that certain passes can be used on both rapid transit and surface, so some overlap occurs.

DISTRIBUTION OF PASSES

Type of Pass	Total Passes		Proportion Used on Surface		Proportion Used Rapid Transit	
	No.	Revenue	No.	Revenue	No.	Revenue
A	17,975	$ 323,550	17,975 (100%)	$323,550 (100%)	--	$ --
B	32,054	705,188	4,327 (13.5%)	43,679 (13.5%)	27,727 (86.5%)	661,509 (86.5%)
C	22,288	802,367	20,288 (91%)	328,569 (41%)	20,288 (91%)	401,585 (50%)
			1,000 (4.5%)	36,106 (4.5%)	1,000 (4.5%)	36,107 (4.5%)
D	4,729	189,160	2,448 (51.8%)	100,256 (53%)	2,448 (51.8%)	88,905 (47%)
			1,050 (22.2%)		1,231 (26.0%)	
E	4,491	215,568	3,241 (72%)	140,119 (65%)	3,241 (72%)	75,449 (35%)
			1,250 (28%)			
F	780	43,680	780 (100%)	21,840 (50%)	780 (100%)	21,840 (50%)
Total	82,317	$2,279,513	52,359	$994,119	56,715	$1,285,395

Other special methods of fare payment include:

	No.	Revenue
• Commutation Tickets (Express Bus and Green Line Only)	2,019	$28,274

• Student Passes

	Mode Taken Using Pass			
	Bus		Rapid Transit	
Type of Student Pass	No.	Revenue	No.	Revenue
Bus Only	7,000	$70,000		
Bus & Rapid Transit	3,338	16,690	3,338	$16,690
	10,338	$86,690	3,338	$16,690

F. The revenue for Period 11, 1982 was distributed to surface and rapid transit lines as follows:

Surface Revenue

Farebox Revenue/Period	= $2,450,621/period	
Non-Farebox Revenue/month	= 1,080,809/month	$1,000,749/period
(Prepaid Pass/month	= 994,119)	
(Student Pass/month	= 86,690)	
Total Surface Revenue	= $3,451,370/period	

Rapid Transit Revenue

Revenue from Tokens Used	= $2,113,602/period
Cash Gate Revenue	= 317,260/period
Pass Revenue $1,285,395/month	= 1,190,181/period
Student Pass $16,690/month	= 15,454/period
Total Transit Revenue	= $3,636,496/period

Total Revenue $7,087,866*

*The MBTA reports Period 11 revenue as $7,292,650. This figure is higher primarily because it does not reflect an adjustment to allocate pass revenue from a monthly basis to an accounting-period basis.

G. The number of unlinked rapid transit trips equals 335,581 riders per average weekday.

Token Trips	= 155,225
Prepaid Pass	= 110,228
Non-pass Cash Gate	= 70,128
Total	335,581

The number of unlinked rapid transit trips/average weekend equals 231,488.

Token Trips	= 116,419
Prepaid Pass	= 66,980
Non-pass Cash Gate	= 48,089
Total	231,488

H. The fare mixes for unlinked rapid transit trips representing a composite value for an average weekday and an average weekend are as follows:

Fare Mix		Weekday 1981	Weekday 1982	Weekend 1981	Weekend 1982
Adult	- Cash	48.5%	49.9%	65.4%	58.2%
	- Pass	29.2%	32.3%	26.2%	28.9%
E & H	- Free	11.1%	8.9%	0.5%	*
	- 1/2 Fare	3.8%	3.2%	5.4%	9.0%
Student & Children	- Pass	--	2.9%	--	--
	- 1/2 Fare	5.8%	1.9%	1.2%	2.0%
Free	- Authorized	1.2%	0.8%	1.0%	0.6%
	- Unauthorized	0.4%	0.2%	0.2%	1.2%
		100.0%	100.0%	100.0%	100.0%

The distribution of riders described in Note D referred only to those rapid transit riders passing through the cash gate. The above fare mix includes all rapid transit riders.

*E & H free fare is not available on weekends.

I. Uses/prepaid pass = $\frac{\text{number of pass trips per period}}{\text{passes sold for rapid transit per period}}$

$= \frac{2,313,807}{60,053/1.08}$

= 41.6 uses per period

= 41.6/21.75 or 1.9 uses per day

(2.0 uses per day per adult pass,
1.7 uses per day per student pass)

J. The average fare for unlinked rapid transit trips was estimated as follows:

$$\text{Average Fare} = \frac{\text{rapid transit revenue}}{\text{number of rapid transit trips}}$$

$$= \frac{\$3,636,496}{(335,581)\ (18.75) + (231,488)\ (4)}$$

$$= \frac{\$3,636,496}{6,292,144 + 925,952} = \frac{\$3,636,496}{7,218,096}$$

$$= \$.504$$

Part II - Surface Transit/Unlinked Trips

K. The MBTA checkers counted passengers on the surface portions of the Green Line and recorded the fare mix during November of 1981 and 1982. The results for both years are shown below (Note that the major difference between the two years is the number of authorized free riders.

		Weekday		Weekend	
Fare Mix		1981	1982	1981	1982
Adult	- Cash	38.4%	29.6%	44.3%	41.6%
	- Pass	25.3%	27.4%	22.9%	21.1%
E & H	- Free	5.9%	3.6%	0.4%	--
	- 1/2 Fare	1.6%	0.9%	4.4%	4.4%
Student & Children	- Pass	0.2%	0.1%	--	--
	- 1/2 Fare	1.1%	1.5%	1.8%	1.3%
Free	- Authorized	27.0%	36.9%	26.2%	31.4%
	- Unauthorized	0	--	--	0.2%
		100.0%	100.0%	100.0%	100.0%
Average Fare*		41.7¢	33.7¢	48.2¢	45.7¢

*Does not include pass revenue.

L. The survey on the bus lines yielded the following distribution of fare payment and average fare.

		Weekday				Weekend*	
		Bus		Trackless Trolley		Bus	
		1981	1982	1981	1982	1981	1982
Fare Mix							
Adult	- Cash	38.6%	35.4%	43.1%	31.3%	46.5%	39.6%
	- Pass	32.1%	33.9%	43.0%	45.1%	28.4%	37.0%
E & H	- Free	7.4%	11.9%	5.7%	12.5%	0.8%	0.0%
	- 1/2 Fare	5.2%	4.1%	5.4%	0.7%	11.7%	14.6%
Students & Children	- Pass	3.2%	4.1%	--	5.0%	0.3%	0
	- 1/2 Fare	12.4%	9.6%	2.4%	5.4%	9.2%	7.1%
Free	- Authorized	0.6%	1.0%	0.4%	0	2.2%	1.5%
	- Unauthorized	0.5%	0	0	0	0.9%	0.2%
		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

	1981	1982	1981	1982
Average Fare** for Bus & Trackless Trolley Combined	40.3¢	36.3¢	41.5¢	41.9¢

*Trackless trolleys do not operate on weekends.
**The average fare represents the weighted average by bus garage and does not include pass revenue.

M. Applying weights in accordance with bus, Green Line and trackless trolley ridership for 1982 (weekdays: 77.5% bus, 20.3% Green Line, 2.3% trackless trolley; weekends: 60% bus, 40% Green Line) yields the following composite fare mix and average fare for surface only, unlinked trips. (See CTPS Techical Report 39 for weights used in 1981.)

COMPOSITE SURFACE FARE MIX AND AVERAGE FARE (Weekday & Weekend)

Fare Mix		1981	1982
Adult	- Cash	39.6%	34.9%
	- Pass	30.7%	32.6%
E & H	- Free	6.3%	8.9%
	- 1/2 Fare	5.3%	4.3%
Student & Children	- Pass	2.3%	2.9%
	- 1/2 Fare	9.9%	7.4%
Free	- Authorized*	5.4%	9.0%
	- Unauthorized	0.5%	--
		100.0%	100.0%
Average Fare **		41.1¢	36.7¢

*Includes passengers riding free in the outbound direction on the surface Green Line.

**Does not include pass revenue.

N. The number of unlinked surface trips per weekday was derived using the average fare ($.367) and the surface revenue.

Surface non-pass revenue/period	= $2,450,621*	
- commutation ticket revenue ($28,274)	= 2,422,347	
- non-pass surface fare ($.367)	= 6,600,400	trips/period
+ 18,700 ticket trips/period (20,196 trips/month)	= 6,619,100	trips/period (non-pass)
- .645 (fraction of total that are non-pass)	= 10,262,171	trips/period
- 21.75 average weekdays/Period 11	= 471,824	unlinked surface trips/weekday

*See Note F.

O. The uses per prepaid pass were estimated as follows:

# of pass trips/period	=	3,643,071 (10,262,171 - 6,619,100)
÷ 58,053 (passes used on surface/period)	=	62.7 trips/pass/period 2.9 trips/pass/day

(3.0 trips per day per adult pass,
1.8 trips per day per student pass)

P. The average fare for unlinked surface-only trips, including passes, equals:

Total Surface Revenue = $3,451,370

÷ 10,262,171 = 33.6¢ for unlinked surface trips
(total surface trips)

Part III - Linked Trips/Average Fare

Q. The number of linked trips per weekday and the average fare for linked weekday trips were estimated as follows:

Unlinked rapid transit trips = 335,581
Unlinked surface trips = 471,824

Rapid transit only = X (29%)
Combination = Y (40%) (percentages from 1978 Systemwide
Surface only = Z (31%) Survey)

$$X + Y = 335,581 \quad (X = 335,581 - Y)$$

$$Z + Y = 471,824 \quad (Z = 471,824 - Y)$$

$$\frac{Y}{X + Y + Z} = .40$$

Solving the third equation:

$$Y = .4X + .4Y + .4Z$$

$$0 = .4X - .6Y + .4Z$$

$$0 = 4X - 6Y + 4Z$$

$$0 = 2X - 3Y + 2Z$$

$$0 = 2(335,581 - Y) - 3Y + 2(471,824 - Y)$$

$$0 = 671,162 - 2Y - 3Y + 943,648 - 2Y)$$

$$Y = \frac{671,162 + 943,648}{7}$$

$$Y = 230,687$$

X = (unlinked rapid transit trips) - Y

$$\begin{array}{r} 335,581 \\ -\ 230,687 \\ \hline \end{array}$$

104,894 rapid transit only

Z = (unlinked surface trips) - Y

471,824
-230,687

241,137 x .85 (.15 surface-to-surface transfers) = 204,966 surface only

X + Y + Z = total linked trips/weekday

104,894
230,687
204,966

540,547 total linked trips/weekday

540,547 x 21.75 = 11,756,897 linked weekday trips/period

Average fare = $\frac{\$\ 7,087,866}{11,756,897} = \$.603$

APPENDIX 2

Survey Samples and Schedules

TABLE A-2a

SURFACE GREEN LINE SURVEY SCHEDULE

	Boston College	Cleveland Circle	Riverside	Arborway
Weekday - Date	11/2	11/3	11/1	11/4
- Valid Trips	28	24	24	26
- Trips Required	12	9	11	9
Weekend - Date	10/30;10/31	10/30;10/31	10/30;10/31	10/30;10/31
- Valid Trips	32	26	39	20

TABLE A-2b

RUNS SAMPLED PER GARAGE

Garage	Total Weekday Runs	Runs Sampled
Cabot	290	12
Arborway	139	6
Bennett (TT)	23	2
Somerville	146	6
Salem	187	8
Quincy	77	3
Lynn	107	4
	969	41

Garage	Total Weekend Runs	Runs Sampled
Cabot	113	4
Arborway	97	5
Somerville	110	5
Salem	132	6
Quincy	62	3
Lynn	71	3
	585	26

TABLE A-2c, p.1

BUS AND TRACKLESS TROLLEY SURVEY SCHEDULE

Day of Week	District	Run Number*	Date of Count
Saturday	Cabot	2002	11/20
		2015	11/20
		2027	11/20
	Arborway	2018	11/20
		2033	11/20
		2401	11/20
		2402	11/20
	Somerville	2009	12/11
		2015	12/11
		2075	12/11
		2081	12/11
	Salem	2008	12/4
		2009	12/4
		2021	12/4
		2029	12/4
		2069	12/4
	Quincy	2024	12/4
		2038	12/4
	Lynn	2005	12/11
		2033	12/11
Sunday	Cabot	3006	11/21
	Arborway	3010	11/21
	Somerville	3013	11/21
	Salem	3401	11/21
	Quincy	3009	11/21
	Lynn	3016	11/21
Weekday	Cabot	1037	11/22
		1071	11/22
		1085	11/22
		1095	11/22
		1104	11/22
		1148	11/22
		9002	11/23
		9027	11/23
		1210	11/23
		1808	11/23
		1809	11/23
		1825	11/23
	Arborway	1004	11/10
		1049	11/10
		1070	11/10
		1071	11/10
		1074	11/10
		1305	11/10
	Bennett (TT)	1504	11/17
		1801	11/17
	Somerville	1034	11/12
		1035	11/12
		1021	11/12
		1080	11/12
		1083	11/12
		1088	11/12

TABLE A-2c, p.2

BUS AND TRACKLESS TROLLEY SURVEY SCHEDULE

Day of Week	District	Run Number	Date of Count
Weekday (cont.)	Salem	1044	11/16
		1084	11/16
		9023	11/15
		9025	11/15
		9043	11/15
		9104	11/15
		9107	11/15
		9134	11/15
	Quincy	1003	11/17
		1015	11/17
		1305	11/17
	Lynn	1006	11/16
		1022	11/16
		1042	11/16
		1053	11/16

*Any run starting with a 9 is manned by a part-time driver.

TABLE A-2d, p.1

RAPID TRANSIT COUNT
COLLECTOR'S TURNSTILE SAMPLE
WEEKDAY
(30 TURNSTILES)

6AM - 10AM (12)

Lechmere
Harvard/Brattle
Andrew
Wonderland
Revere
Orient Heights
Arlington
Malden
Charles
Fields Corner
Shawmut
Government Center

11AM - 2PM (7)

Dudley
Dover
Auditorium
Malden
State-Blue
North Station
Quincy Center

3PM - 6PM (8)

Dudley
South Station
Government Center
Maverick
Sullivan
Park Under
Haymarket-Green

6PM - 10PM (3)

Essex
Harvard/Brattle
Harvard

TABLE A-2d, p.2

RAPID TRANSIT COUNT
COLLECTOR'S TURNSTILE SAMPLE
WEEKEND
(24 TURNSTILES)

Saturday (12)

6AM - 10AM (4)

Sullivan
Wollaston
Prudential
State-Blue

10AM - 2PM (4)

Malden
Airport
Auditorium
Arlington

2PM - 6PM (4)

Harvard/Brattle
North Quincy
Copley
Northampton

Sunday (12)

6AM - 10 AM (4)

Egleston
So. Braintree
Wonderland
Canal-No. Station

10AM - 2PM (4)

Oak Grove
Dudley
Arlington
Government Center

2PM - 6PM (4)

North Quincy
Copley
Washington-Red
Haymarket-Green

TABLE A-2e

RAPID TRANSIT STATIONS
GATEMEN ASSIGNMENTS

Stations	Gatemen Hours	Total Hours
State-North	3:00 PM - 6:00 PM	3
Washington-North	12:15 PM - 6:15 PM	6
Dudley	6:45 AM -10:00 AM	3.25
	11:00 AM - 3:30 PM	4.5
Egleston	7:15 AM - 9:00 AM	1.75
	9:00 AM - 3:00 PM	6
Forest Hills	6:30 AM - 9:30 AM	3
	12:30 PM - 3:30 PM	3
Harvard/Brattle	6:30 AM - 9:30 AM	3
	12:30 PM - 3:30 PM	3
Andrew	6:30 AM - 9:30 AM	3
	12:30 PM - 3:00 PM	2.5
Fields Corner	6:30 AM - 9:30 AM	3
	12:30 PM - 3:30 PM	3
Ashmont	6:30 AM - 9:30 AM	3
	12:30 PM - 3:30 PM	3
Canal	1:30 PM - 3:30 PM	2
Park	3:00 PM - 4:45 PM	1.75
	4:45 PM - 7:30 PM	3.75
Copley	10:45 AM - 3:00 PM	4.25

TABLE A-2f

RAPID TRANSIT STATIONS
"UNAUTHORIZED" GATE ASSIGNMENT

Time Period	6 - 10 AM	10 - 2 PM	2 - 6 PM	6 - 10 PM
Stations	Copley INB Wollaston Quincy Ctr. Gov't Ctr.	Wellington Central South Kendall South	Essex South Orient Heights Kendall North Haymarket Green	Auditorium

APPENDIX 3

Average Weekday Pass Usage by Garage and Rapid Transit Line

AVERAGE WEEKDAY PASS USAGE
ON SURFACE TRANSIT BY GARAGE

Arborway	13.75%
Cabot	30.48
Salem*	3.10
Charlestown**	19.62
Lynn	4.33
Quincy	4.28
Bennett (TT)	2.23
Green Line	22.21
	100.00%

*Includes Fellsway Garage only.
**Includes Salem St. district, Charlestown Garage and entire Somerville bus district.

AVERAGE WEEKDAY PASS USAGE BY RAPID TRANSIT LINE

Orange Line	29.7%
Red Line*	25.9%
Blue Line	7.6%
South Shore Extension	5.9%
Green Line**	30.9%
	100.0%

*Does not include the So. Shore Extension -- No. Quincy to Braintree.
**Does not include surface portion.

APPENDIX 4

Survey Forms

FARE MIX AND RIDERSHIP CHARACTERISTICS
GREEN LINE SURVEY FORM

| | | |

FARE MIX AND RIDERSHIP CHARACTERISTICS
RAPID TRANSIT STATION SURVEY FORM (COLLECTOR'S TURNSTYLE)

NAME		STATION	
DATE		ENTRANCE	
DAY OF WEEK		START TIME	O AM O PM

PASSENGER COUNTING

TIME PERIOD					
E & H	HALF FARE				
	FREE				
STUDENTS & CHILDREN	HALF FARE				
	PASS				
ADULTS	CASH FARE				
	PASS				
OTHER FREE	AUTHORIZED				
	NON AUTHORIZED				

PASSENGER READING

READING	BEGIN:	READING	END:

FARE BOX AND METER READINGS

CASH	BEGIN:	CASH	END:
PENNY	BEGIN:	PENNY	END:
TOKEN	BEGIN:	TOKEN	END:
TURNSTYLE METER	BEGIN:	TURNSTYLE METER	END:
PASSMETER	BEGIN:	PASSMETER	END:

COLLECTORS TURNSTILE TALLY SHEET

STATION/ ENTRANCE		TIME PERIOD	

E & H	HALF FARE	
	FREE	
STUDENTS & CHILDREN	HALF FARE	
	PASS	
ADULTS	CASH FARE	
	PASS	
OTHER FREE	AUTHORIZED	
	NON AUTHORIZED	

FARE MIX AND RIDERSHIP CHARACTERISTICS
BUS SURVEY FORM

NAME		DATE	1 2 3 4 5
GARAGE	6 7	BUS #	8 9 10 11
RUN #	12 13 14 15	ROUTE #	16 17 18
DIRECTION	O INBOUND O OUTBOUND 19	START TIME	O AM O PM 20 21 22 23

PASSENGER COUNTING

ADULT	CASH FARE		24 25 26
	PASS		27 28 29
E & H	HALF FARE		30 31 32
	FREE		33 34 35
STUDENT & CHILDREN	HALF FARE		36 37 38
	PASS		39 40 41
OTHER FREE	AUTHORIZED		42 43 44
	NON AUTHORIZED		45 46 47

FARE BOX READING

CASH	BEGIN: 48 49 50 51 52	CASH	END: 53 54 55 56 57		
PENNY	BEGIN: 58 59 60 61 62	PENNY	END: 63 64 65 66 67		
TOKEN	BEGIN: 68 69 70 71 72	TOKEN	END: 73 74 75 76 77		
$ BILLS				78 79 80	

Fare Mix and Ridership Characteristics

Rapid Transit Station Survey Form (Gate w/ Attendants)

Name		Station	
Date		Entrance	
Day of the Week		Start Time	○ A.M. ○ P.M.

Passenger Counting

Time Period	Prepaid Pass	Full Fare	Other	Total

Passenger Reading if Any

Reading	Begin:	End:

Fare Box Reading

Cash	Begin:	End:
Penny	Begin:	End:
Token	Begin:	End:

Remarks

MASS. MP03.2: M45/2/983

CTPS TECHNICAL REPORT 48

1983 MBTA FARE-MIX SAMPLING PROGRAM: ANALYSIS AND DOCUMENTATION

GOVERNMENT DOCUMENTS
COLLECTION
SEP 16 1985
University of Massachusetts
Depository Copy

December 1984

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CTPS TECHNICAL REPORT 48

TITLE 1983 Fare-Mix Sampling Program: Analysis and Documentation

AUTHOR(S) Evelyn Y. Addante

DATE December 1984

ABSTRACT This report describes the assumptions and methods used to design and administer a sampling program to determine the fare mix and average fare for rapid transit, buses, and the surface Green Line. The information obtained from this program was used in conjunction with revenue data to determine the number of unlinked and linked trips made on rapid-transit and surface routes in November 1983.

This document was prepared by **CENTRAL TRANSPORTATION PLANNING STAFF**, an interagency transportation planning staff created and directed by the Metropolitan Planning Organization, consisting of the member agencies.

Executive Office of Transportation and Construction
Massachusetts Bay Transportation Authority
Massachusetts Department of Public Works
MBTA Advisory Board
Massachusetts Port Authority
Metropolitan Area Planning Council

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This document was prepared in cooperation with the Urban Mass Transportation Administration of the U S. Department of Transportation through the technical study grant(s) cited below, and was also financed with state and local matching funds.

MA-09-0095
MA-09-0107
MA-08-0115

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ACKNOWLEDGMENTS

The sampling program used this year and previous years was designed and developed with the invaluable assistance of Alan Castaline and other MBTA personnel. The formidable task of data collection was performed by the MBTA traffic checkers.

1.0 INTRODUCTION

Historically, the MBTA has estimated daily and annual ridership by dividing collected revenue by an average fare. In 1981 it was decided that, because of various fare and system changes, the average-fare figure being used was no longer valid. In addition, accurate data were needed to develop pricing and marketing policies and to satisfy federal reporting requirements.

Therefore, in November of 1981, the MBTA instituted a new program for estimating ridership whereby the average fare used to calculate the number of riders from revenue is determined by surveying a sample of actual ridership. The number of passengers boarding, the type of fare they paid, and farebox revenue are recorded for selected bus routes, on the surface portions of the Green Line, and at selected rapid-transit stations. The resulting data are processed and analyzed by the Central Transportation Planning Staff (CTPS). This program has now been in effect for three years.

This report is an update of the previous CTPS technical reports on this subject. It presents the 1983 survey results and analysis procedures and the two previous years' results. The analysis, as well as the results, of the 1981 and 1982 fare-mix surveys are available in CTPS Technical Reports 39 and 43.

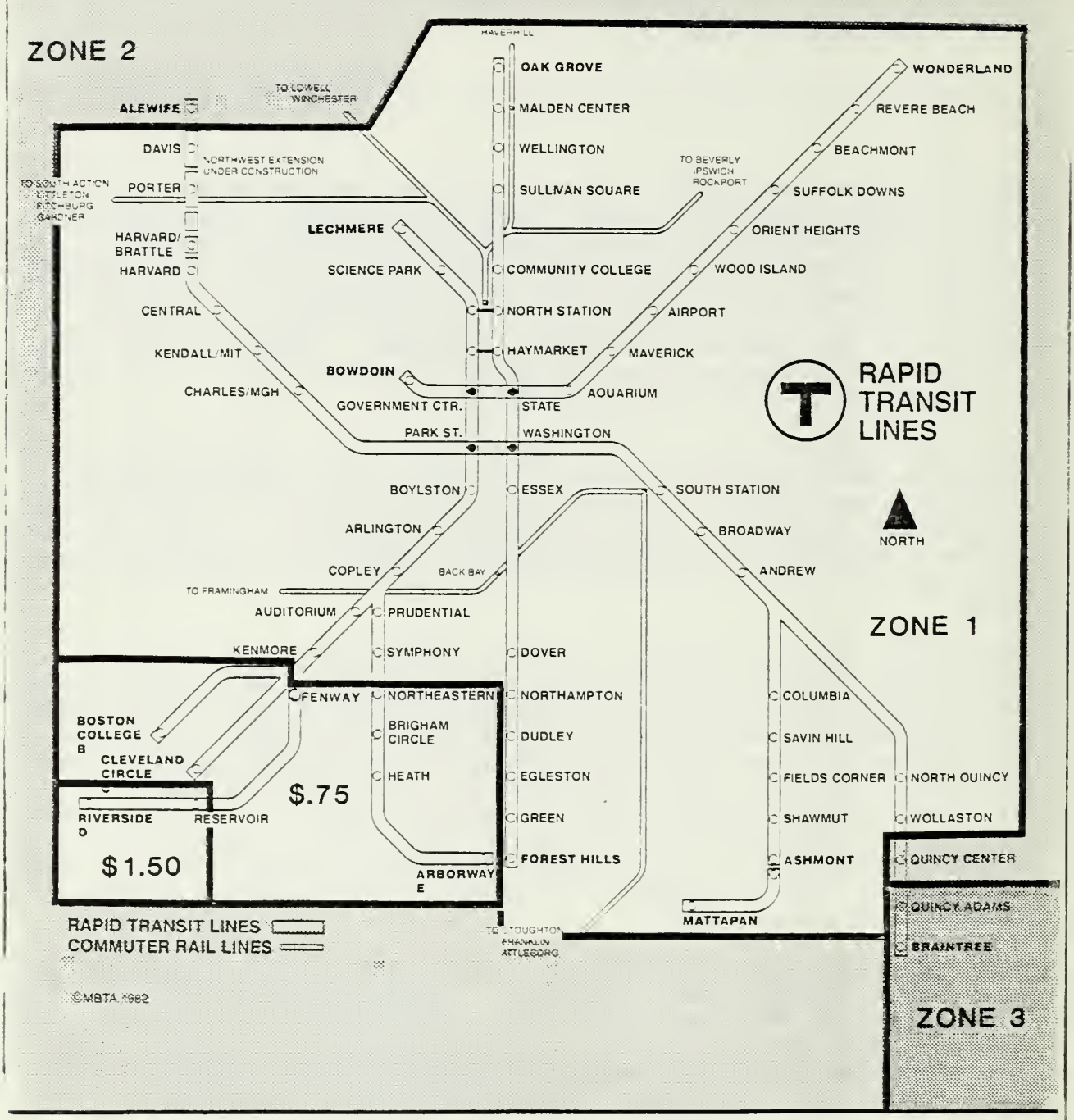
2.0 MBTA TRANSIT SERVICE

The MBTA operates public transit on three rapid-transit lines (Red, Orange, and Blue), five light-rail branches (comprised by the Green Line and the Mattapan high-speed line), trackless-trolley routes, bus routes, and commuter-rail lines (not covered in this report). The Green Line is a combination of low-platform streetcar service on the surface and rapid-transit or subway service in the downtown and Back Bay areas. Figure 2-1 is a map of the transit system, showing fares by zone; Table 2-1 presents the fare tariff for the bus system.

The basic adult cash fares are sixty cents for rapid-transit and subway Green Line service and fifty cents for trackless-trolley and local bus service. There are zoned fares on some local bus routes and a range of fares on express bus routes. Fares on the surface portion of the Green Line are paid in the inbound direction only and range from seventy-five cents to a dollar and a half.

Riders can also purchase a variety of pre-paid monthly passes which have no limit on the number of times that they can be used. The elderly (65 and over) pay a ten-cent fare at all times except for express bus and zoned bus trips beyond the local area, for which they pay one-half the adult fare. The handicapped pay the full adult fare for peak-hour travel (7:00-9:00 A.M. and 4:00-6:00 P.M. weekdays) and the elderly fare at all other times. Children between five and twelve pay half-fare at all times. Students in grades K-12 pay half-fare during school hours if they have proper identification. Students can also obtain monthly passes from their schools.

All fares are paid as passengers board buses and trolleys and as they enter rapid-transit stations. (Passengers also pay an additional fare as they leave the Zone 3 rapid-transit stations (Quincy Adams and Braintree). In rapid-transit stations, tokens are deposited before passengers pass through the regular, full-fare turnstiles. At least two turnstiles per station are equipped to read electronically the pre-paid passes (not including student passes). Those who pay reduced fares or no fare are supposed to use turnstiles at the collector's booths (referred to as collector's turnstiles in this report). "Gateman's boxes," which allow passengers paying any type of fare to pass through, are open in several stations (primarily at peak travel times).



ZONE 1 - $.60 - $.30 - $.10

ZONE 2 - $.90 - $.45 - $.10

ZONE 3 - $1.20 - $.60 - $.10

ADULT STUDENT & CHILDREN ELDERLY

1983 MBTA Fare-Mix Sampling Program Technical Report 48 December 1984	RAPID-TRANSIT NETWORK AND ZONAL FARES (1983)	CTPS FIGURE 2-1

Zone	Route Miles*	Adult Fare**	Student & Child Fare	Elderly Fare
1	0 - 6	$0.50	$ .25	$ .10
2	6 - 9	0.75	.35	$ .35
3	9 - 12	1.00	.50	.50
4	12 - 15	1.25	.60	.60
5	15+	1.50	.75	.75

*Zone fares may be adjusted based on geographic, topographic, or other distinctive circumstances in order to establish logical boundaries.

**NOTES ON ADULT FARE:

- Base Fare - $0.50, good for all routes that are less than 6 miles and for the first 6-mile zone on routes longer than 6 miles.
- Zone Fares - Additional $0.25 for each 3-mile increment.
- Express Premium - Additional $0.25 for express bus services.
- Maximum Fare - $1.50, including express premium.

3.0 TRANSIT-SERVICE AND -FARE CHANGES BETWEEN 1981, 1982 and 1983

It is important to realize that apparent increases or decreases in transit ridership between 1981, 1982, and 1983 in several categories can, in part, be attributed to transit-service or -fare changes. For example, in December 1982, the revoking of the elderly-and-handicapped off-peak free fare had an impact on surface-transit ridership. In addition, refinements to survey and data-analysis techniques have influenced survey results. Attempts have been made in this section and the next to point out these differences and how they affect the data.

3.1 SERVICE CHANGES

3.1.1 1981-1982

In November 1981, when the fare-mix survey was conducted, the Dorchester Branch of the Red Line (between Columbia and Ashmont stations) and the Mattapan High Speed Line were not in service because new track was being laid. The people who normally used these portions of the system were bused to Andrew or North Quincy stations. The token turnstiles at these stations, particularly Andrew, were not designed to handle the increased passenger load during the A.M. and P.M. peaks; therefore, many of those who used tokens and prepaid passes, as well as those who paid cash, went through the collector's turnstiles and the open gates that were monitored by gatemen. This resulted in uncharacteristically high figures for usage of the collector's turnstiles and gateman's boxes. It should also be pointed out that the 1981 sampling program did not allow for surveying those who made local trips on the substitute bus service for the Dorchester Branch.

The Arborway Branch of the Green Line was also not in operation during November 1981. Inbound Arborway users were bused to Copley Station, where they went through gates without paying an additional fare, thereby influencing gate counts at Copley. Service was restored on this branch in June 1982. The addition of Arborway riders in the 1982 sample of the surface Green Line influenced the average fare for the Green Line.

3.1.2 1983

Rapid-transit service in 1983 was the same as in 1982, with two exceptions. On September 3, 1983, Quincy Adams Station opened. This station is located between Quincy Center and Braintree stations on the southern extension of the Red Line.

Currently, the effect of the opening of this station on ridership levels is being analyzed. At the other end of the Red Line, the Harvard/Brattle and Harvard/Holyoke stations were closed in September 1983, and all passengers began using Harvard Station. On surface transit a few new routes were added and some changes made to existing routes between 1982 and 1983; overall, these changes did not alter the character of the system.

3.2 FARE CHANGES

3.2.1 1981-1982

The base rapid-transit fare was seventy-five cents in November 1981. It was reduced to sixty cents in May 1982. Student passes were available only for bus trips during 1981. Boston public-school students who used rapid transit were issued tokens for thirty-five cents apiece. Beginning in September 1982, student passes were available which could be used on either mode. The base fare for surface transit did not change between 1981 and 1982.

3.2.2 1983

The basic adult fare for surface transit and rapid transit did not change from 1982 to 1983. The free off-peak elderly fare (9:30 A.M.-4:00 P.M., Monday-Friday) with half-fare for the elderly at all other times was replaced by a ten-cent fare at all times, except for express bus, zoned bus beyond the local area, and commuter rail. This fare change resulted from a bill passed by the legislature that became effective on December 20, 1982.

4.0 SAMPLING TECHNIQUES AND DATA-COLLECTION PROCEDURES

4.1 OVERVIEW

Ridership is estimated from revenue using an average fare determined from the fare mix. The sampling program was designed to find the fare mix. Sampling techniques for 1983 are essentially the same as those used in past years. A summary of these techniques is provided below.

The average fare can be calculated as follows:

$$F_a = (F_f \times P_f) + (F_r \times P_r)$$

where F_a = average fare
F_f = full fare
F_r = reduced fare
P_f = % passengers who pay full fare
P_r = % passengers who pay reduced fare

The degree of precision or confidence interval of the average fare can be calculated as follows:

$$\pm [CIP_f \times F_f + (CIP_r \times F_r)]$$

where CIP = confidence interval of the fare mix (P_f and P_r, respectively)

For the purposes of the sampling program, the confidence interval of the fare mix was set at $\pm$2.5 percent and the confidence level (allowable degree of risk) at 95 percent. These parameters mean that the probability of the estimated fare mix differing by more than 2.5 percent from the actual fare mix is one in twenty.

To determine the fare mix, the least complicated sampling technique available was the simple random sample wherein each item or individual had an equal chance of being selected. The number of observations (or the size) for this type of sample is determined by the confidence interval, the confidence level, and the nature of the results required (in this connection, seen in terms of proportions of riders). The formula used to calculate the sample size was:

$$No = pq \frac{t^2}{d^2}$$

where No = the required sample size
p = the unknown proportion
q = the remaining proportion
d = the interval size
t = the statistic which relates the confidence level to the normal curve

The "unknown" and "remaining" proportions correspond, respectively, to the percentage of riders who pay full adult fare and the percentage who pay other than full fare. For the purpose of calculating sample size, these proportions were estimated to be fifty/fifty, which produced the largest possible proportions. (Note that of all possible proportions, fifty/fifty is always most conducive to a large sample size.) Using the given parameters, the formula yields a sample size of 1,536, which was rounded to 1,540.

After the sampling program was completed, actual confidence intervals obtained were calculated by using the formula

$$\pm\ a\sqrt{\frac{P_S Q_S}{N}}$$

where a = coefficient of confidence level
P_S = sampling proportion
Q_S = the remaining proportion
N = the number of observations

For example, if 1,600 passengers were counted and the following data were obtained:

Fare mix: Full fare = 65% (P_f)
Reduced fare = 25% (P_r)
Free = 10%

Fare: Full fare = 60¢
Reduced fare = 30¢

then the confidence interval of the fare mix at a 95-percent confidence level would be:

$$\underline{\text{Full fare}} = 1.96 \times \sqrt{\frac{.65(.35)}{1,600}} = \pm 2.34\%$$

or 65% $\pm$ 2.34% = 62.66% to 67.34%

$$\underline{\text{Reduced fare}} = \pm\ 1.96 \times \sqrt{\frac{.25(.75)}{1,600}} = \pm 2.12\%$$

or 25% $\pm$ 2.12% = 22.88% to 27.12%

The average fare would be:

(60¢ x .65) + (30¢ x .25) = 46.5¢

and the confidence interval of the average fare would be:

(.0234 x .60) + (.0212 x .30) = 2.04¢

or 46.5¢ $\pm$ 2.04¢ = 44.5¢ to 48.5¢

4.2 SURFACE TRANSIT (BUS, TRACKLESS TROLLEY, AND SURFACE GREEN LINE)

4.2.1 Bus and Trackless Trolley, 1981-1982

Surface-transit revenue is calculated by district; therefore, a sample was drawn from each one. Within a given district, a driver's daily duty assignment is called a "run," which includes trips on one or several routes. It was decided that the bus-and-trackless-trolley sample should be based on runs, since the people doing the counts could then be assigned to a driver for a day and not have to worry about making connections with other vehicles. Note that the use of runs may not always insure an unbiased estimate for the population as a whole; however, given constraints on time and resources, it is the most efficient method available.

The number of runs sampled per district was pro-rated according to the proportion of district runs to total runs. The resulting number of runs to be sampled per district ranged from 2 to 12 for the weekday sample and from 3 to 5 for the weekend sample. (The total number of runs sampled was determined through estimating the average number of passengers per trip.) All runs were listed by district and the selections were made by using a random-numbers table.

Only one traffic checker per run was needed to collect data for the bus-and-trackless-trolley sample. He sat behind the driver and recorded the number of people boarding and the type of fare paid (adult full-fare, student pass, etc.), farebox readings, and other pertinent information.

4.2.2 Bus and Trackless Trolley, 1983

As in previous years, the sample-selection process was based on driver runs. Because of manpower constraints during November, it was necessary to reduce the number of runs sampled. This could be done without a loss in statistical significance since four out of the seven districts were over-sampled in 1982. Results were weighted according to the number of daily scheduled runs by district. The number of sampled runs per district ranged from two to six, for a total of 30 runs compared to 41 for 1982. Two runs from each district were sampled on Saturday and one run on Sunday. These runs were selected by using a random-numbers table (Table A-2 in Appendix 2 lists the selected runs).

4.2.3 Surface Green Line, 1981-1982

For the surface Green Line, in 1981, a simple random sample of runs was selected at the Reservoir Garage, from which Green Line cars are dispatched. Traffic checkers were assigned to specific runs, which meant that they had to stay on a particular car until their shifts ended. They counted people boarding inbound on the

surface portion, recorded the type of fare paid, and recorded surface revenue; then they rode underground to the end of the line, rode back in the outbound direction, and counted people boarding outbound on the surface (no fares are collected). Among the problems encountered were frequent farebox malfunctions, which meant that sometimes there was no revenue figure (and therefore no average fare) for an entire run. The procedure was confusing to the checkers and they frequently failed to count those boarding in the outbound direction; even though a portion of the survey was conducted a second time, some faulty data were still obtained.

In 1982, it was decided that the sample of the surface Green Line should be based on trips instead of runs. The 1978 system-wide survey was used to determine the minimum number of inbound trips that had to be surveyed per time period, by branch. The same number of outbound trips per period also had to be surveyed. The first A.M. inbound trip to be boarded by a given checker on a given survey day was selected randomly (from trips before 6:05 A.M.). The checker rode in on that trip, got off at Kenmore (Symphony on the Arborway branch), and got on the next outbound car on the branch to which he had been assigned. Therefore, if a car had a faulty farebox meter, only one, rather than a series, of surveyed trips had unusable data. The 1982 outbound count was much more accurate than that of 1981. Although the data show an increase in outbound ridership, the nature of the changes between the two years is unclear given the inaccuracy of the 1981 data.

4.2.4 Surface Green Line, 1983

The surface Green Line survey was conducted in a manner similar to that of 1982. Once again, it was necessary to reduce the number of trips sampled. The inbound starting time for a given checker was the same as in 1982. After riding in on that trip and disembarking at Kenmore, a checker could then get on the next outbound car on any line. A minimum number of inbound trips to be sampled per line controlled this procedure (see Table 4-1). Results were weighted based on the number of scheduled trips per line.

4.3 RAPID TRANSIT

4.3.1 1981-1982

At rapid-transit stations, only collector's-booth turnstiles and gateman's boxes required manual counting, since the regular turnstiles, when functioning properly, provide the necessary data on token and prepaid-pass usage. Traffic checkers recorded the number of people passing the gateman's box by method of fare payment. They recorded turnstile readings at the collector's-booth turnstiles (and at the regular turnstiles, as a back-up to the data provided by the MBTA).

DISTRIBUTION OF INBOUND SURFACE-GREEN-LINE BOARDINGS BY BRANCH AND TIME PERIOD*

	Riverside	Boston College	Cleveland Circle
6:00-9:00 A.M.	36.0%	27.2%	35.8%
9:00-3:00 P.M.	36.1	46.6	42.0
3:00-6:00 P.M.	21.3	20.5	16.5
6:00-Midnight	6.6	5.7	5.8
Total	100.0%	100.0%	100.1%

MINIMUM INBOUND TRIPS TO BE SURVEYED PER PERIOD**

	Riverside	Boston College	Cleveland Circle	Arborway
6:00-9:00 A.M.	3	3	3	2
9:00-3:00 P.M.	3	4	3	3
3:00-6:00 P.M.	2	2	1	1
6:00-Midnight	1	1	1	1
Total	9	10	8	7

*Source: 1978 Systemwide Survey

**Arborway was not surveyed in 1978; however, it was felt that the Arborway ridership profile closely resembles that of the Cleveland Circle Branch.

During an average weekday, 13 percent of all rapid-transit users pass through collector's-booth turnstiles at 54 stations. For each station, the proportion of riders using the collector's turnstile to total riders systemwide using the collector's turnstile in each of four time periods was calculated. These proportions were listed in a table on a station-by-time-period basis and organized into four groups, three of which represented roughly equal percentages of the total. Only a minor proportion of passengers were accounted for in the fourth group; therefore, it was decided that it would be inefficient to sample that group. It was initially determined that 1,500 passengers should be sampled from each group, but, when the fourth group was eliminated, the sample size was increased for each of the other groups and cells were drawn from the first, second, and third groups equally.

In 1982, as in 1981, a relatively small number of rapid-transit stations had gateman's boxes that were authorized to be open, so all of these were counted. However, it was discovered that gates at many stations were open unofficially. Therefore, a random sample of these was selected for counting.

4.3.2 1983

The number of rapid-transit stations at which collector's turnstiles were sampled was reduced from 29 to 23. The starting point for making the selection was last year's station choices. Stations were deleted so as to maintain a sample representative of the three station groups described above in section 4.2.1. Gateman's boxes at rapid-transit stations were also sampled. No sample was taken at unofficial gates in 1983; 1982 survey results were used for this component of the analysis.

5.0 DATA-ANALYSIS PROCEDURES AND RESULTS

The following discussion summarizes the data analysis and results of the Fare-Mix Sampling Program for unlinked and linked trips. A more detailed explanation of the data-analysis procedures is given in Appendix 1.

For the purpose of this survey, an unlinked surface trip is defined as a trip made using one surface vehicle, and an unlinked rapid-transit trip is defined as a trip made on the rapid-transit system (including the underground portion of the Green Line) and can include transfers from one rail-transit line to another. A linked trip is defined as one trip from origin to destination and includes transfers. For example, if one were to ride a bus from near one's home to a rapid-transit station and there board the subway for the remainder of the trip to work, one linked trip would be the result.

5.1 UNLINKED TRIPS

5.1.1 Rapid Transit

- Data-Analysis Procedure

Token and passmeter readings and the amount of cash taken in at the various booths are recorded daily for rapid transit by the MBTA. These data, augmented with sample data from the survey of collector's turnstiles and gateman's boxes and additional revenue data from the MBTA, were used to estimate average fare and unlinked rapid-transit trips. Some adjustments to the data on tokens were made because turnstiles at Quincy Center, Quincy Adams, and Braintree require more than one token. Adjustments were also made to passmeter readings for missing or inaccurate data due to broken meters. Estimated pass usage by rapid-transit line for 1983 is presented in Appendix 3.

- Results

The estimated rapid-transit fare mix, average fare, and number of unlinked trips for 1983, and for 1981 and 1982 as well, are presented in Table 5-1. The number of unlinked rapid-transit trips increased by 9.8 percent between 1981 and 1982 and by 3.6 percent between 1982 and 1983. The average fare was 60¢ in 1981, decreased to 50.4¢ in 1982 and remained almost the same in 1983 (51.0¢). Adult cash and pass use categories combined represent between 78 and 82 percent of all fare payment in the three survey periods. Adult pass use increased by 3 percent between 1981 and 1982 and remained at 32.3 percent (the 1982 level) in 1983.

		1981	1982	1983
Fare Mix				
Adult	- Cash	48.5%	49.9%	48.6%
	- Pass	29.2	32.3	32.3
Elderly & Handicapped	- Free	11.1	8.9	NA
	- 1/2 Fare	3.8	3.2	NA
	- Reduced	NA	NA	13.5
Students & Children	- 1/2 Fare	5.8	1.9	1.6
	- Pass	NA	2.9	3.3
Free	- Authorized	1.2	0.8	0.5
	- Unauthorized	0.4	0.2	0.2
		100.0%	100.0%	100.0%
Average Fare		60.0¢	50.4¢	51.0¢
Total Unlinked Trips (Average Weekday)[1]		305,000	335,581	347,514

NA = not applicable

[1]Includes pass trips

1983 MBTA Fare-Mix Sampling Program	RAPID-TRANSIT FARE MIX, 1981-1983 (WEEKDAY)	CTPS
Technical Report 48 December 1984		TABLE 5-1

The predominant reason for the decrease in the average fare from 1981 to 1982 is the reduction in the basic adult fare from 75¢ in 1981 to 60¢ in 1982. Another reason is the increase in adult pass use and the availability of rapid-transit student passes.

5.1.2 Surface Transit (Surface Green Line, Buses, and Trackless Trolleys)

- Data-Analysis Procedure

The data used to estimate the average fare were obtained from a survey of the surface portions of the Green Line and selected bus and trackless-trolley routes. Traffic checkers counted passengers and recorded their method of fare payment and the fare-box readings.

- Results

In Table 5-2 the fare mix and average fare for the surface portion of the Green Line are presented. Between the 1981 and 1982 survey periods, the average fare decreased by 8¢, from 41.7¢ to 33.7¢. In 1983, the average fare was 37.4¢, 3.7¢ higher than in the 1982 survey period.

Noteworthy among the changes in the fare-mix proportions are those in the authorized-free component. In the 1982 survey period this category accounts for almost 37 percent of all use, while the corresponding figures for 1981 and 1983 are 27 percent and 31.2 percent, respectively. The 1982 proportion does not appear consistent with the survey results of 1981 and 1983.

The bus and trackless-trolley fare mix and average fare are presented by bus garage in Table 5-3 and summarized by year in Table 5-4. Between the three survey periods there are significant fluctuations in fare-category proportions and average fares. From 1981 to 1982, pass use increased for all but two garages, as did the proportion of elderly and handicapped who paid no fare. Several garages had substantial increases in the latter category. In contrast, between 1982 and 1983, there are decreases in the proportion of all elderly and handicapped users for four out of the seven garages.[1]

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[1] For the Quincy garage there was a substantial increase in the elderly-and-handicapped fare category. The sample for this garage was not as large as preferred and the randomly selected runs included routes which provide service to a large apartment complex for the elderly and handicapped. This may have biased the sample.

		1981	1982	1983
Fare Mix				
Adult	- Cash	38.4%	29.6%	31.1%
	- Pass	25.3	27.4	28.0
Elderly & Handicapped	- Free	5.9	3.6	-
	- 1/2 Fare	1.6	0.9	-
	- Reduced	-	-	7.3
Students & Children	- 1/2 Fare	1.1	1.5	1.5
	- Pass	0.2	0.1	0.8
Free	- Authorized	27.0	36.9	31.2
	- Unauthorized	0.0	-	0.1
		100.0%	100.0%	100.0%
Average Fare[1]		41.7¢	33.7¢	37.4¢
Confidence Interval of Average Fare		N.A.	±1.0¢	±1.2¢

[1]The average fare represents the weighted average of the four components of the surface Green Line and does not include pass revenue.

1983 MBTA Fare-Mix Sampling Program	SURFACE GREEN LINE FARE MIX 1981-1983 WEEKDAY	CTPS
Technical Report 48 December 1984		TABLE 5-2

	ARBORWAY			CABOT[1]			SALEM[2]			SOMERVILLE[3]		
	1981	1982	1983	1981	1982	1983	1981	1982	1983	1981	1982	1983
Adult Cash	31.8%	33.3%	30.9%	37.9%	32.9%	40.2%	38.9%	37.6%	38.1%	45.1%	37.6%	35.4%
Prepaid Pass	28.4	34.3	36.8	34.5	40.9	37.8	21.7	32.1	31.0	40.9	34.9	32.7
E&H Half Fare	7.0	2.5	-	3.4	3.5	-	5.9	8.1	-	4.2	3.3	-
E&H Free	7.6	13.8	-	6.3	11.1	-	10.6	6.2	-	3.6	12.8	-
E&H Reduced Fare	-	-	12.3	-	-	8.2	-	-	10.5	-	-	15.3
Student and Children Half-Fare	17.0	10.6	11.9	10.3	7.5	7.8	21.3	11.4	18.3	4.8	9.2	15.2
Student Pass	6.0	5.2	7.6	6.1	3.2	5.2	0.8	4.5	1.6	0.6	1.5	1.1
Authorized Free	1.0	0.3	0.5	0.5	0.9	0.8	0.5	0.1	0.5	0.6	0.7	0.2
Unauthorized Free	1.2	0.0	0.0	0.7	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Average Fare[4]	35.0¢	32.6¢	37.7¢	41.0¢	38.2¢	44.3¢	39.4¢	37.2¢	35.1¢	42.7¢	36.0¢	36.7¢
Actual Confidence Interval	NA	±1.2¢	±1.7¢	NA	±.9¢	±1.5¢	NA	±1.4¢	±1.6¢	NA	±1.2¢	±1.6¢

[1]Includes Albany Garage [2]Includes Fellsway Garage [3]Includes Charlestown [4]Does not reflect pass revenue

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BUS AND TRACKLESS-TROLLEY FARE MIX AND AVERAGE FARE BY GARAGE, 1981-1983
(Weekday)

CTPS

TABLE
5-3(a)

	LYNN			QUINCY			BENNETT		
	1981	1982	1983	1981	1982	1983	1981	1982	1983
Adult Cash	29.3%	40.1%	37.9%	42.3%	36.0%	33.4%	43.5%	31.3%	37.9%
Prepaid Pass	28.7	18.6	27.7	20.1	21.7	21.8	44.2	45.1	36.5
E&H Half Fare	3.7	4.5	-	8.9	3.9	-	5.5	0.7	-
E&H Free	13.6	19.2	-	11.2	10.7	-	4.6	12.5	-
E&H Reduced Fare	-	-	12.7	-	-	21.0	-	-	10.5
Student and Children Half-Fare	24.4	9.7	10.6	16.7	14.8	22.4	2.0	5.4	10.2
Student Pass	0.4	4.3	10.6	0.0	11.3	1.1	0.8	5.0	3.4
Authorized Free	0.0	3.5	0.5	0.9	1.6	0.2	0.2	0.0	1.5
Unauthorized Free	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Average Fare	42.9¢	37.1¢	48.9¢	39.1¢	34.0¢	32.9¢	42.1¢	35.4¢	37.6¢
Actual Confidence Interval	NA	±1.8¢	±2.2¢	NA	±2.0	±2.2¢	NA	±1.5¢	±1.7¢

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BUS AND TRACKLESS-TROLLEY FARE MIX AND AVERAGE FARE BY GARAGE, 1981-1983
(Weekday)

CTPS

TABLE 5-3(b)

Fare		1981	1982	1983
Adult	- Cash	39.1%	35.1%	36.7%
	- Pass	33.3	34.7	33.2
Elderly & Handicapped	- 1/2 Fare	5.2	3.8	-
	- Free	7.2	11.9	-
	- Reduced	-	-	11.9
Students & Children	- 1/2 Fare	11.4	9.3	13.0
	- Pass	2.9	4.2	4.5
Free	- Authorized	0.5	0.9	0.5
	- Unauthorized	0.4	0.0	0.0
		100.0%	100.0%	100.0%
Average Fare[1]		40.3¢	36.3¢	39.7¢
Confidence Interval of Average Fare		N.A.	±.6¢	±.7¢

[1]Does not reflect pass revenue

1983 MBTA Fare-Mix Sampling Program	BUS AND TRACKLESS-TROLLEY FARE MIX 1981-1983 (WEEKDAY)	CTPS
Technical Report 48 December 1984		TABLE 5-4

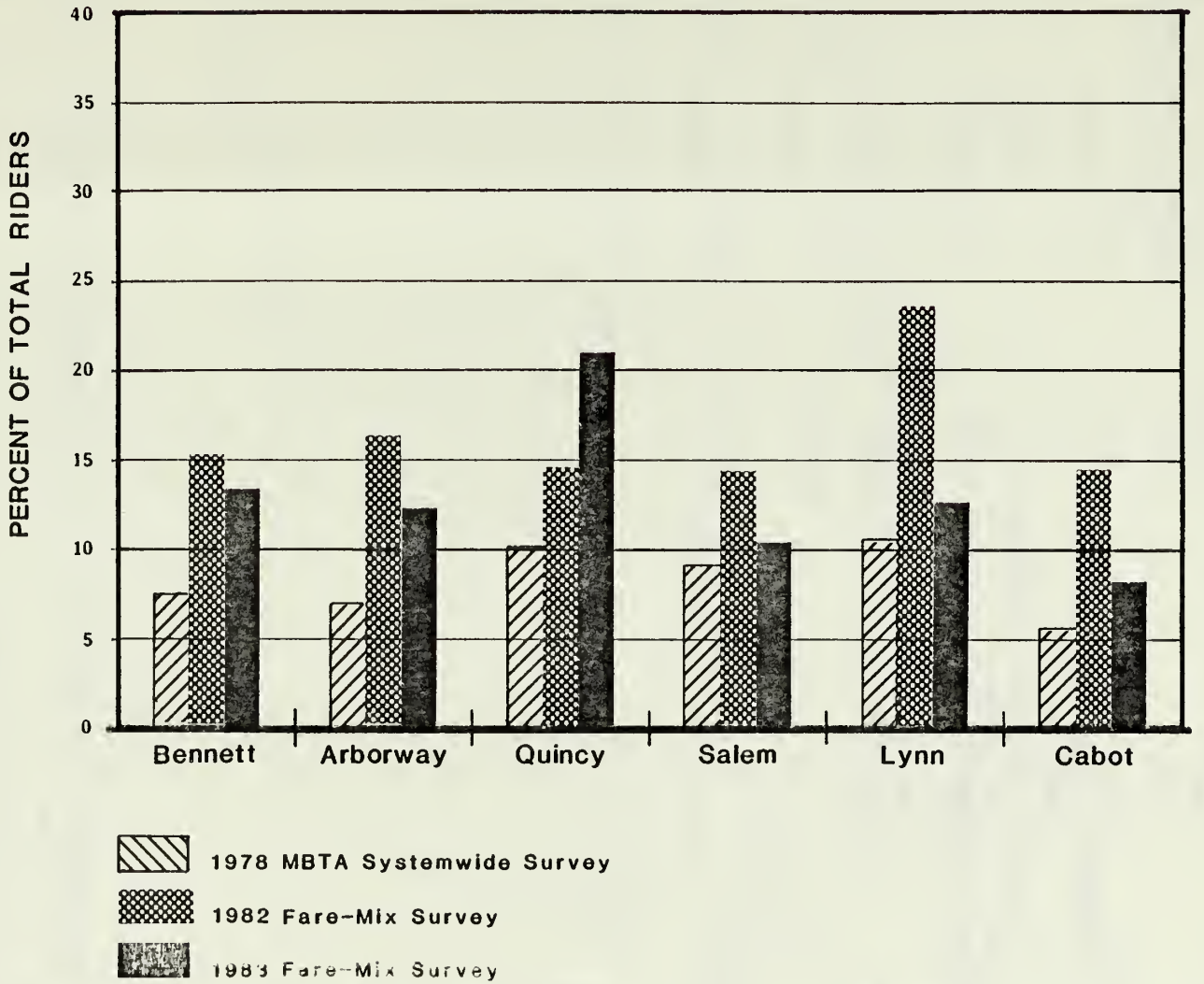
The proportion in the elderly-and-handicapped category was compared to results obtained from the bus section of the 1978 MBTA system-wide survey. As shown in Figure 5-1, the percent of 1982 riders who were elderly and handicapped is markedly higher than the percent of 1978 riders who were elderly (because handicapped riders constitute only a small portion of total riders, this comparison is valid). In 1978, the elderly composed 7.9 percent of all bus riders, while in 1982 the proportion of elderly and handicapped was 15.7 percent and in 1983, 11.9 percent.

The decrease in the average fare between 1981 and 1982 cannot be explained for surface transit, as it was for rapid transit, by a change in the fare structure. The free off-peak elderly fare, instituted in late 1981, affected a small proportion of total riders. It may have resulted in a slight reduction in the average fare, but not a reduction of the magnitude indicated by the survey results. Similarly, the increase in the average fare between 1982 and 1983 cannot be explained by the replacement of the off-peak elderly fare with a ten-cent fare in effect at all times. It is difficult to determine the actual reasons for the low estimated average fare in 1982. However, comparison of the results from the 1978 MBTA bus survey and the 1982 fare-mix survey point to an oversampling of the elderly fare category.

To produce a composite estimate of the surface-transit fare mix and average fare, weights in accordance with the percent of total surface ridership were applied to the surface-Green-Line, trackless-trolley, and bus fare mixes. The results are presented in Table 5-5. Once again, 1982 results appear inconsistent with 1981 and 1983. The fare categories of 1981 and 1983 are within one percentage point of each other with one exception. Likewise, the average fares of the two years vary by only 2¢. The 1982 average fare of 36.7¢ is lower than either 1981 or 1983, and the 1982 distribution of use among fare categories shows more variation when compared with 1981 and 1983 than the 1981-to-1983 comparison.

The findings regarding the average-fare and ridership estimates from the 1982 survey required adjustments to be made. In Table 5-6, the number of estimated trips, the average fare, and other summary data are presented for surface transit in 1981, 1982, and 1983. Two sets of figures are provided for 1982; the enclosed numbers are revised values, while the unenclosed indicate survey results. The implications of the low unrevised average fare for 1982 can be seen by comparing estimates of average weekday trips. The number of estimated trips using the unrevised fare increases from 1981 to 1982 and then decreases from 1982 to 1983, whereas survey-period revenue is lower in 1982 than either 1981 or 1983. The estimated number of pass trips is highest in 1982, yet pass sales also increased each survey period from 1981 to 1983.

To provide average-fare and ridership estimates more compatible with 1981 and 1983 results, the number of 1982 surface-transit



1983 MBTA Fare-Mix Sampling Program Technical Report 48 December 1984	ELDERLY AND HANDICAPPED RIDERSHIP 1978, 1982, and 1983	CTPS FIGURE 5-1

		1981	1982	1983
Fare Mix				
Adult	- Cash	36.9%	34.9%	36.4%
	- Pass	30.7	32.6	31.4
Elderly & Handicapped	- Free	6.3	8.9	-
	- 1/2 Fare	5.3	4.3	-
	- Reduced	-	-	11.0
Student & Children	- 1/2 Fare	9.9	7.4	9.3
	- Pass	2.3	2.9	3.1
Free	- Authorized[1]	5.4	9.0	8.7
	- Unauthorized	0.5	-	-
		100.0%	100.0%	100.0%
Average Fare[2]		41.1¢	36.7¢	39.1¢

[1]Includes passengers riding free in the outbound direction on the surface Green Line.

[2]Does not include pass revenue.

1983 MBTA Fare-Mix Sampling Program	WEIGHTED SURFACE-TRANSIT FARE MIX 1981-1983 (WEEKDAY & WEEKEND)	CTPS
Technical Report 48 December 1984		TABLE 5-5

	1981	1982	1982	1983
Unlinked Average-Weekday Trips				
Pass	139,301	167,498	147,410[1]	152,652
Cash	282,824	304,326	279,866	289,818
Total	422,125	471,824	427,276	442,470
Survey-Period Revenue	$3,656,678	$3,451,370		$3,614,588
Average Fare	39.6¢	33.6¢	37.1¢[1]	37.6¢
Pass Sales (Nov.)	58,184	62,697		70,164
Uses per Pass/Period	53	58	51[1]	48

[1]Revised

1983 MBTA Fare-Mix Sampling Program Technical Report 48 December 1984	SURFACE-TRANSIT SUMMARY 1981, 1982, AND 1983	CTPS TABLE 5-6

trips was re-computed, based on the ratio of surface trips to rapid-transit trips in 1983. Pass trips were then derived by applying the 1983 percent pass use to total surface trips. Finally, the average fare, uses per pass, and linked trips were calculated.

5.2 LINKED TRIPS

5.2.1 Data-Analysis Procedures

In order to link rapid-transit and surface trips, an estimate of the proportion of rapid-transit-only, surface-only, and combination (rapid transit and surface) trips is needed. For this year's analysis, as for last year's, the source used was the 1978 Systemwide Survey, which included a question about transfer behavior. Because of service cuts, fare increases, and transit-line extensions that took place after that survey was taken, 1981 proportions were changed slightly to 31-percent rapid-transit-only, 30-percent surface-only, and 39-percent combination. By November 1982, however, much of the cut service had been restored, and rapid-transit and pass fares had been reduced. Therefore, the 1978 proportions of 29 percent, 31 percent, and 40 percent, respectively, were thought to be more appropriate.

The actual process for linking trips for 1982 was not the same as that used in 1981, because it was felt that the accuracy of the 1981 process could be improved by assuming that the proportion of combination trips is more accurate than the individual surface-only and rapid-transit-only proportions. Simultaneous equations were used to find the total number of combination trips, which was then subtracted from total unlinked rapid-transit trips and total unlinked surface trips to find rapid-transit-only and surface-only trips.

The 1981 trips were re-linked using the new method so that the results would be compatible with those of subsequent years.

5.2.2 Results

The average fare decreased from 71.1¢ in 1981 to 63.5¢ in 1982, while there was an increase of 4.6 percent in the number of average-weekday linked trips (from 490,900 in 1981 to 513,500 in 1982). This estimate of linked trips is based on the revised 1982 unlinked surface trips discussed in section 5.1.2. Based on the original survey results, the number of linked trips in 1982 would have been 540,547, with an average fare of 60.3¢. In 1983 the number of linked trips was 531,760, an increase of 3.6 percent over 1982, and the average system-wide fare was 64.1¢. Compared with the original 1982 survey results, the number of 1983 linked trips would have represented a 1.6-percent loss in average weekday ridership.

The calculations for 1983 linked trips are summarized in Appendix 1.

6.0 STATISTICAL ANALYSIS

The estimated average fare mix can be used to estimate boardings within a confidence interval of ±2.5 percent.

The actual confidence intervals at a 95-percent confidence level and sample sizes for the bus system, the Green Line, and collector's turnstiles are presented on the following pages. Except for fare mixes by bus garage, the confidence intervals are less than ±2.5 percent.

	Weekday	Weekend
Adult Cash	±0.93%	±1.46%
Adult Pass	±0.91%	±1.36%
E&H Reduced Fare	±0.64%	±1.10%
Student & Children 1/2 Fare	±0.66%	±0.71%
Student Pass	±0.39%	-
Authorized Free	±0.15%	±0.39%
Unauthorized Free	±0.02%	±0.09%

*95% confidence level

1983 MBTA Fare-Mix Sampling Program Technical Report 48 December 1984	ACTUAL CONFIDENCE INTERVALS* BUS	CTPS TABLE 6-1

	Arborway	Cabot	Salem	Somerville	Lynn	Quincy	Bennett
Adult Cash	±2.41%	±2.19%	±2.28%	±2.27%	±2.64%	±3.01%	±2.73%
Adult Pass	±2.52%	±2.16%	±2.17%	±2.23%	±2.43%	±2.64%	±2.71%
E&H Reduced Fare	±1.71%	±1.22%	±1.44%	±1.71%	±1.81%	±2.60%	±1.73%
Student and Children 1/2 Fare	±1.69%	±1.19%	±1.81%	±1.71%	±1.68%	±2.66%	±1.71%
Student Pass	±1.38%	±0.99%	±0.59%	±0.50%	±1.67%	±0.65%	±1.02%
Authorized Free	±0.37%	±0.40%	±0.33%	±0.23%	±0.40%	±0.29%	±0.68%
Unauthorized Free	-	-	-	-	-	±0.21%	-

*95% confidence level

1983 MBTA Fare-Mix Sampling Program Technical Report 48 December 1984	ACTUAL CONFIDENCE INTERVALS* BY BUS GARAGE (WEEKDAY)	CTPS TABLE 6-2

	Arborway	Cabot	Salem	Somerville	Lynn	Quincy	Bennett	TOTAL
Adult Cash	436	776	667	602	492	315	459	3,747
Adult Pass	519	729	542	556	359	206	441	3,352
E&H Reduced Fare	173	158	184	260	165	198	127	1,265
Student and Children 1/2 Fare	167	150	320	258	138	211	124	1,368
Student Pass	107	101	28	19	137	10	41	443
Authorized Free	7	16	9	4	7	2	18	63
Unauthorized Free	0	0	0	0	0	1	0	1
TOTAL	1,409	1,930	1,750	1,699	1,298	943	1,210	10,239

1983 MBTA Fare-Mix Sampling Program
Technical Report 48
December 1984

NUMBER COUNTED BY BUS GARAGE AND FARE TYPE

CTPS
TABLE 6-3

	Weekday		Weekend	
	Number Counted	Confidence Interval	Number Counted	Confidence Interval
Adult Cash	1,505	±1.27%	1,827	±1.29%
Adult Pass	1,426	±1.25%	1,229	±1.14%
E&H Reduced Fare	316	±0.67%	274	±0.60%
Student and Children 1/2 Fare	72	±0.33%	59	±0.28%
Student Pass	32	±0.22%	-	-
Authorized Free	1,676	±1.31%	1,877	±1.29%
Unauthorized Free	2	±0.06%	2	±0.05%
TOTAL	5,029		5,268	

*95% confidence level

1983 MBTA Fare-Mix Sampling Program Technical Report 48 December 1984	ACTUAL CONFIDENCE INTERVALS* SURFACE GREEN LINE	CTPS TABLE 6-4

	Weekday		Weekend	
	Number Counted	Confidence Interval	Number Counted	Confidence Interval
Adult Cash	387	±1.08%	1,964	±1.42%
Adult Pass	743	±1.41%	1,314	±1.30%
E&H Reduced Fare	1,563	±1.69%	789	±1.08%
Student and Children 1/2 Fare	380	±1.07%	254	±0.65%
Student Pass	191	±0.78%	-	-
Authorized Free	63	±0.46%	298	±0.71%
Unauthorized Free	26	±0.30%	24	±0.21%
TOTAL	3,353		4,643	

*95% confidence level

1983 MBTA Fare-Mix Sampling Program Technical Report 48 December 1984	ACTUAL CONFIDENCE INTERVALS* COLLECTOR'S TURNSTILES	CTPS TABLE 6-5

7.0 SUMMARY AND RECOMMENDATIONS

7.1 SUMMARY

The purpose of the annual fare-mix survey is to provide current data on the type of fare paid by a sample of transit riders. From this information is derived an average fare, which, combined with revenue data, is used to estimate current ridership.

For the purpose of the survey, the MBTA system is divided into three sections: surface transit, rapid transit, and the surface portions of the Green Line. MBTA checkers surveyed trips from each component to provide separate estimates of average fare and unlinked ridership. These figures are combined to produce an estimate of linked trips and an estimated average fare.

Table 7-1 provides a summary of the average fare and ridership estimates for 1981, 1982, and 1983. Both linked and unlinked trips have increased from 1981 through the current survey period.

The estimate for 1983 of 531,760 linked trips reflects an increase of 3.6 percent over the 1982 estimate of 513,500 trips. The 1982 estimate is 4.6-percent higher than the 490,000 trips of 1981. The current average fare of 64.1¢ is only slightly higher than the 1982 average fare of 63.5¢. The 1981 average fare of 71.1¢ was considerably higher due to the 75¢ basic adult rapid-transit fare in effect during the survey period.

The cost of conducting the count is estimated to have been approximately $31,000; the preparation, processing, and analysis of data also cost approximately $31,000.

7.2 RECOMMENDATIONS

The following points should be taken into consideration in planning and implementing all future surveys.

- The mechanical condition of transit-system data-collection devices continues to be a problem during the implementation of a survey, as well as at other times. There should be an ongoing program of regular maintenance to ensure that accurate data are obtained throughout the year, particularly at rapid-transit stations.

- Due to scheduling and personnel constraints, the number of people counted in the 1983 sample was about 33-percent less than in 1982. As noted in the 1982 report, the sample size in that year was much larger than needed to ensure statistical

	Rapid Transit			Surface Transit		
	1981	1982	1983	1981	1982[2]	1983
Unlinked Average Weekday Trips						
Token	141,759	155,255	157,143			
Pass - Passmeter	(77,044)	(87,647)	(90,116)			
- Passholders using gates or collector's turnstiles	(13,301)	(22,581)	(29,876)			
Subtotal	90,345	110,228	119,992	139,301	147,410	152,652
Cash	73,595	70,128	70,379	282,824	279,866	289,818
Total	305,699	335,581	347,514	422,125	427,276	442,470
Survey Period Revenue	$3,932,827	$3,636,496	$3,797,495	$3,656,678	$3,451,370	$3,614,588
Average Fare	60.0¢	50.4¢	51.0¢	39.6¢	37.1¢	37.6¢
Pass Sales (Nov.)[1]	50,432	60,053	68,894	58,184	62,697	70,164
Uses per Pass/Period	38	39	37	53	61	48

	1981	1982	1983
Linked Trips per Average Weekday	490,900	513,500	531,760
Average Fare	71.1¢	63.5¢	64.1¢

[1]Pass sales for the month of November are given to provide a consistent base for uses per pass/period.
[2]Revised

1983 MBTA Fare-Mix Sampling Program Technical Report 48 December 1984	SUMMARY OF 1981-1983 AVERAGE-FARE AND RIDERSHIP CALCULATIONS	CTPS TABLE 7-1

validity. Therefore, this year's reduced sample size did not affect the validity of the results. In two of the smaller districts the number of runs sampled did not provide the required sample. If in the next survey the fare-mix is still desired by district, the number of runs selected from these districts should be increased.

- The bias in the 1982 survey toward the elderly-and-handicapped fare category may be the result of a large proportion of the survey taking place during off-peak times, when the free elderly fare was in effect (it has not been ascertained whether this proportion of the surveying was in fact large). If another time-related fare category is instituted in the future, this type of bias may again be an issue. To avoid the problem, the time of day should be controlled in the survey.

APPENDIX 1

Annotated* Flow Diagram

of

1983 Fare-Mix and Ridership Estimation

		Page
Overview		39
Part I:	Rapid Transit	41
Part I.B:	Rapid-Transit Cash-Gate Trips	43
Part II:	Surface Transit	59
Part III:	Linked Trips and Average Fare	69

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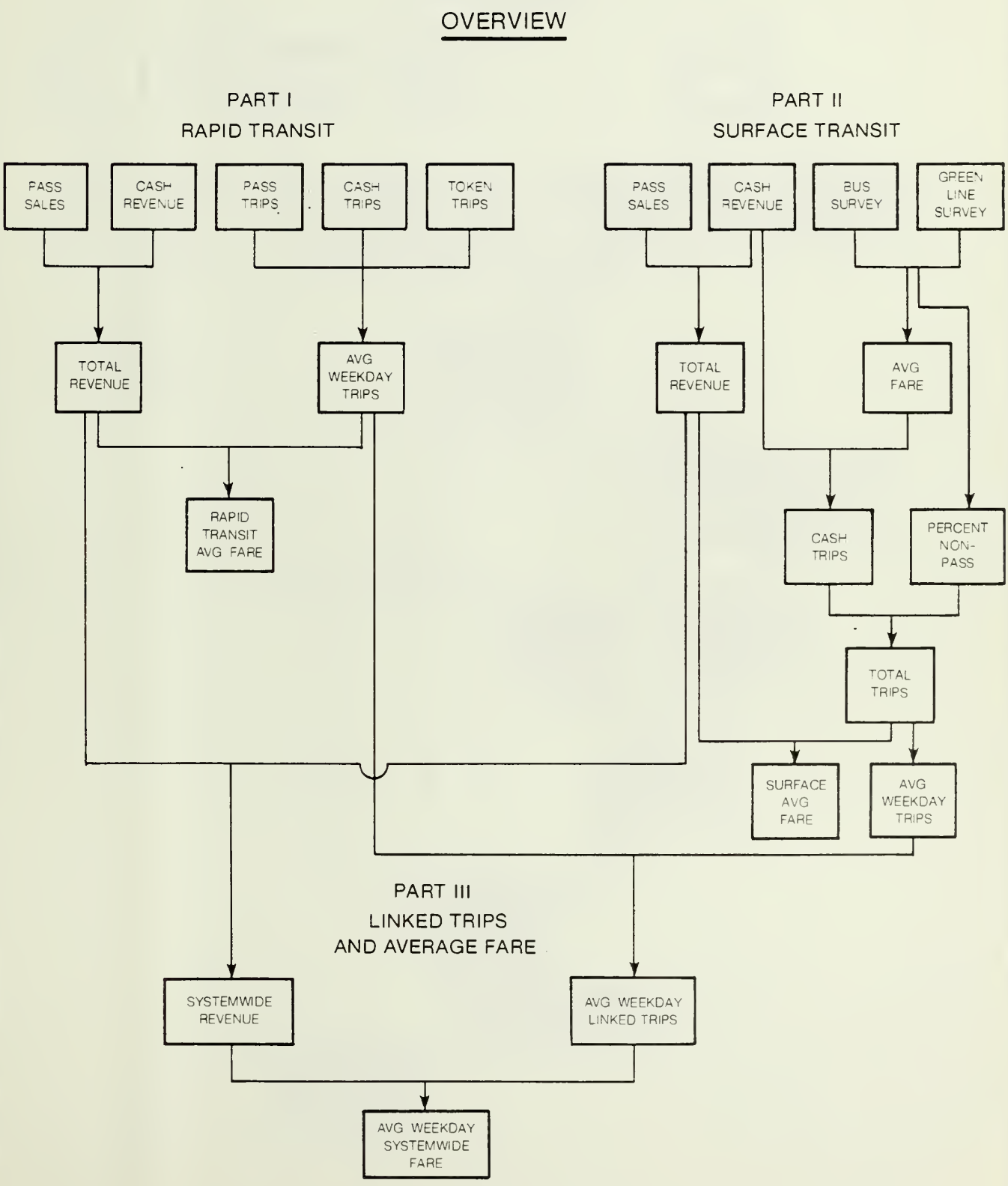
*Notes, which follow each part of the diagram, are referred to by the designations at the upper right-hand corner of diagram boxes.

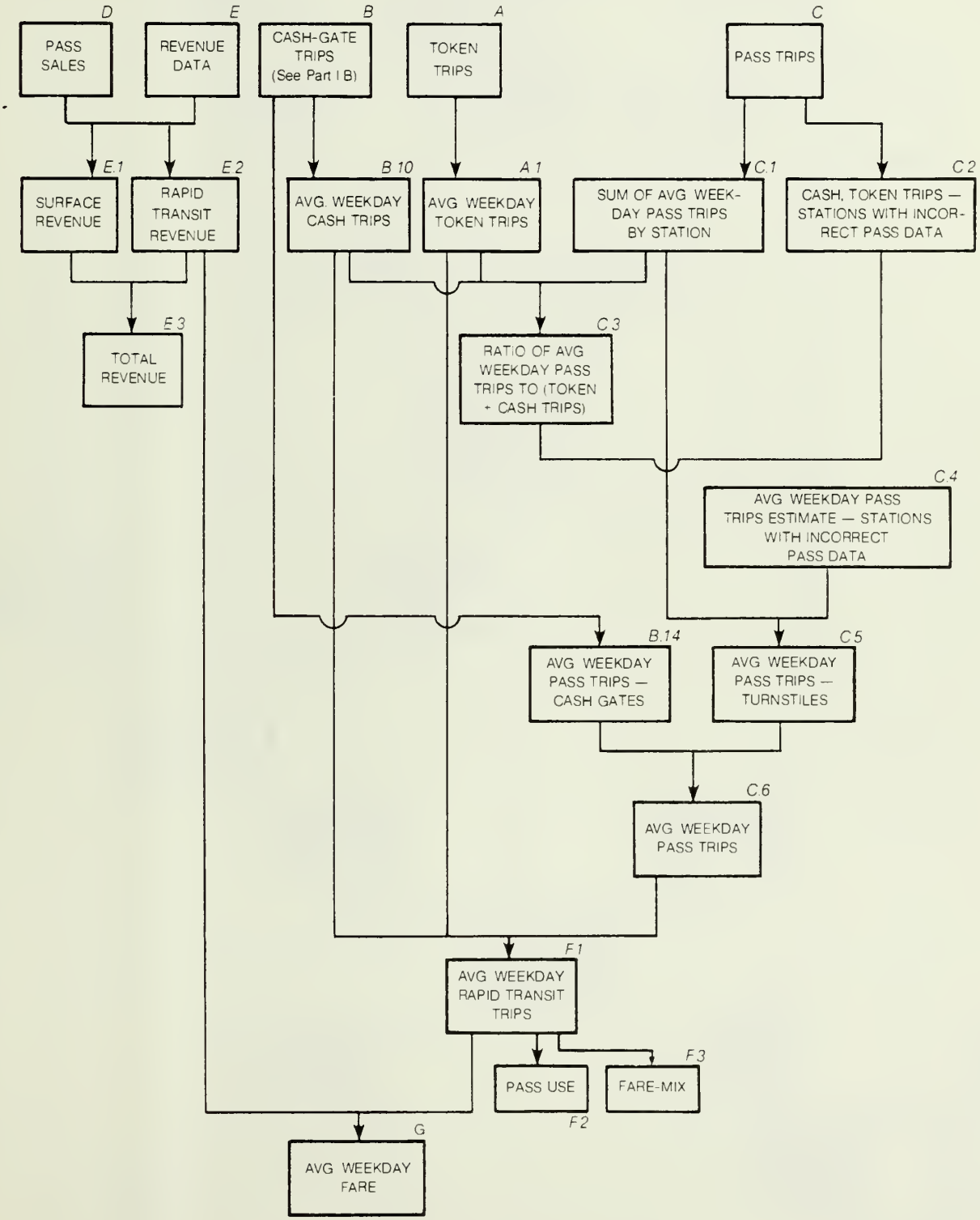
FLOW DIAGRAM OF 1983 FARE-MIX AND RIDERSHIP ESTIMATION



FLOW DIAGRAM OF 1983 FARE-MIX AND RIDERSHIP ESTIMATION

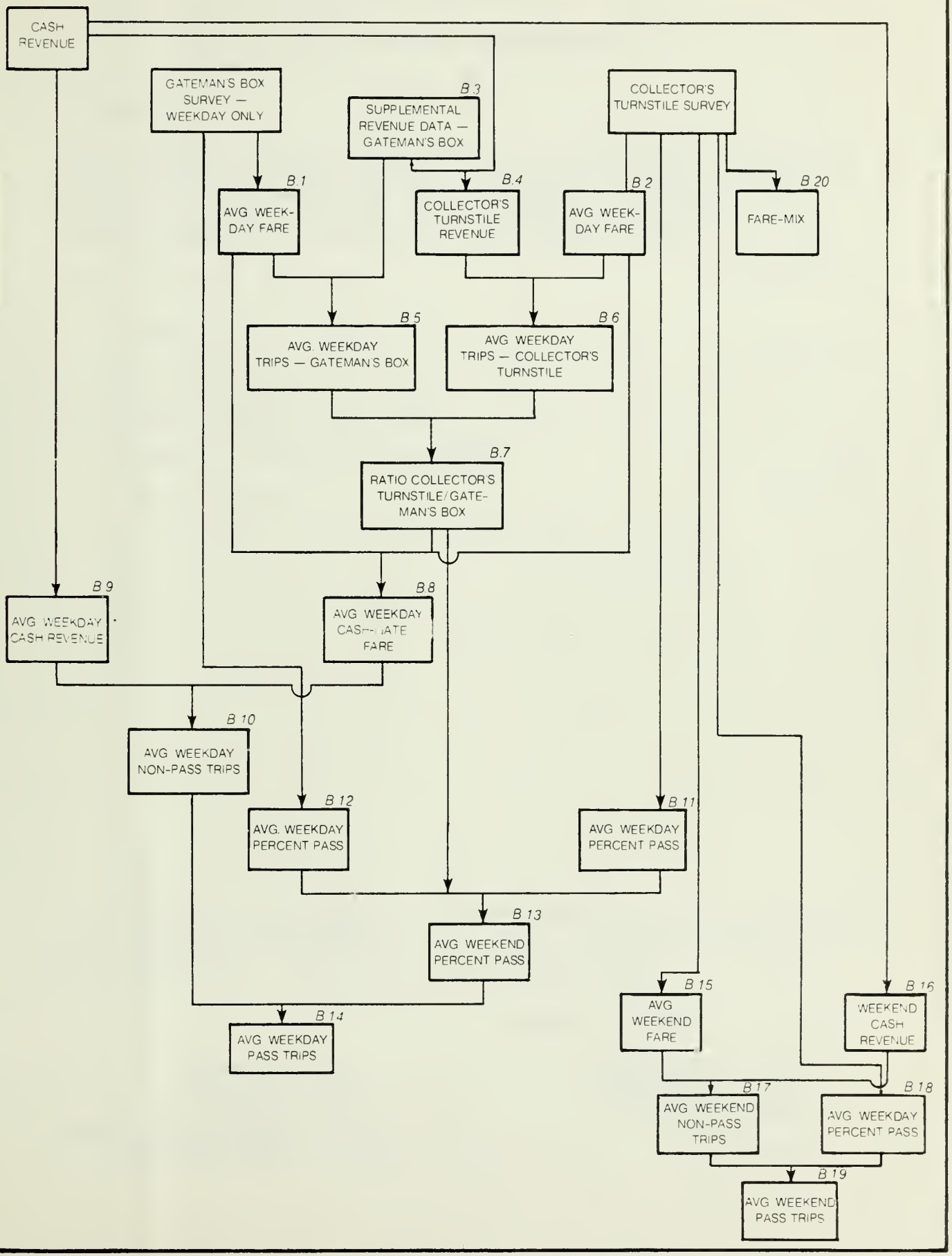
PART I

RAPID TRANSIT



FLOW DIAGRAM OF 1983 FARE-MIX AND RIDERSHIP ESTIMATION

PART I.B
RAPID TRANSIT CASH-GATE TRIPS



NOTES

Part I - Rapid Transit (Unlinked Trips)

A. TOKEN TRIPS

The number of tokens used in Period 5, 1983, was obtained from the MBTA's RTL210 report. In this analysis, token trips rather than the number of tokens received is used. Since some stations require two or more tokens, the number of tokens received is greater than the actual number of trips.

Token trips in Period 5	= 3,417,853

A.1 Average weekday token trips

3,417,853 ÷ 21.75[1]	= 157,143

A.2 Average weekend token trips

Weekend as percent of weekday	= 75%
.75 x 157,143	= 117,857

---

[1]21.75 represents the number of weekday-equivalent days in period 5, 1983 (October 29-November 25). It is calculated from factors which reflect the type of schedule (as a percent of a weekday schedule) that is in effect on a particular date.

Weekday = 1.00	
Saturday = 0.50	
Sunday = 0.25	
Thanksgiving Day = 0.25	
Veteran's Day = 0.50	

Period 5, 1983:

Weekdays =	18.00
4 Weekends =	3.00
Holidays =	0.75
	21.75

B. CASH-GATE TRIPS

The number of people using cash gates is estimated as a function of the cash received at rapid-transit stations, the weighted average fare of patrons using collector's turnstile and gateman's boxes, and the average pass use.

Daily cash receipts for each station are provided by the RTL210 report. These figures include cash received at gateman's boxes and collector's turnstiles combined. Supplemental data on daily cash receipts at gateman's boxes is provided by the MBTA. By using this data, collector's-turnstile cash can then be separated from total cash receipts.

Surveys of gateman's boxes and collector's turnstiles provide passenger counts and cash collected. From this information, an average weekday fare is derived for both locations and an average weekend fare for collector's turnstiles, (gateman's boxes are not surveyed on the weekend because, at most, only two stations have them open). Average pass use is also estimated from survey results.

Average Weekday Fare and Non-Pass Ridership

B.1	Average weekday fare at gateman's boxes (survey data)	=	31.3¢
B.2	Average weekday fare at collector's turnstiles (survey data)	=	20.9¢
B.3	Period 5[1] gateman's-box revenue (weekdays) (supplemental revenue data)	=	$57,938
B.4	Period 5[1] collector's-turnstile revenue (weekdays) (RTL210 cash receipts - gateman's-box cash)	=	$207,419
B.5	Gateman's-box average weekday trips (used only for weighting average cash-gate fare)	=	10,428
B.6	Collector's-turnstile average weekday trips (used only for weighting average cash-gate fare)	=	55,912
B.7	Relative proportion of trips using collector's turnstiles/gateman's boxes	=	(.842)/(.157)
B.8	Weighted average weekday fare (.842)(.209) + (.157)(.313)	=	22.5¢

[1]Omits three days' cash revenue received in October

B.9 Cash receipts ÷ avg. weekdays
Period 5 Period 5

344,415 ÷ 21.75 = $15,835

B.10 Average weekday non-prepaid pass users at cash gates, 15,835 ÷ .225 = 70,379

Average Weekday Pass Use

B.11 Collector's turnstiles (survey data) = 27.9%

B.12 Gateman's boxes (survey data) = 40.3%

B.13 Weighted average weekday pass use[2]
(.842)(.279) + (.157)(.403) = 29.8%

B.14 Average weekday pass trips
(non-pass users) ÷ (proportion non-pass)
70,379 ÷ .702 = 100,255
100,255 - 70,379 = 29,876

Average Weekend Fare and Non-Pass Ridership

B.15 Average weekend fare at collector's turnstiles = 39.7¢

B.16 Period 5[1] cash receipts (weekends) (4 weekends) = $73,652

Average weekend revenue = 18,413

B.17 Average weekend ridership, 18,143 ÷ .397 = 46,381

Average Weekend Pass Use

B.18 Average pass use = 28.3%

B.19 Average weekend pass ridership
46,381 ÷ .717 = 64,688
64,688 - 46,381 = 18,307

---

[1]In 1982, pass use was presented as a percent of non-pass riders rather than total riders.

The corresponding figures for 1983 would be: Weekday 43.1%
Weekend 39.5%

[2]Omits three days' cash revenue received in October

B.20 Fare Mix at Collector's Turnstiles

	Weekday			Weekend		
	1981	1982	1983	1981	1982	1983
Adult Cash	7.5%	12.1%	16.0%	51.1%	38.2%	59.0%
E&H						
- Free	52.2%	50.5%	-	3.0%	-	-
- 1/2 Fare	15.0%	21.0%	-	31.4%	43.4%	-
- Reduced	-	-	64.6%	-	-	23.7%
Students & Children 1/2 Fare	18.9%	10.9%	15.7%	7.1%	9.8%	7.6%
Free						
- Authorized	4.9%	4.2%	2.6%	6.0%	2.8%	9.0%
- Unauthorized	1.5%	1.3%	1.1%	1.4%	5.7%	0.7%
Average Fare	17.5¢	18.9¢	20.9¢	51.7¢	39.3¢	39.7¢

C. PASS TRIPS

Passmeter readings for each rapid-transit station are given in the MBTA's RTL210 report. Total values for the period cannot be used as a measure of pass trips because passmeters at a number of stations are disabled, registering no values or incorrect ones. To obtain a more reasonable estimate of pass trips, an average weekday value was calculated for each station, excluding those days with missing or incorrect information. For those stations where no values or too few were recorded to arrive at an average, an estimated value was derived based on pass trips at other stations as a percent of token and cash trips.

In the following calculations, average weekday and weekend pass, token, and cash trips were obtained from turnstile data.

	Average Weekday	Average Weekend
C.1 Pass trips		
Stations with usable pass data	78,499	29,480
C.2 Token trips		
Stations without pass data	19,535	53,207
Stations with pass data	137,608	64,650
Total	157,143	117,857
Cash trips		
Stations without pass data	8,993	16,812
Stations with pass data	55,188	29,565
Total	64,181	46,381

Average Weekday Pass Trips

C.3 Average weekday pass trips as a percent of cash and token trips
78,499 ÷ (55,188 + 137,608) = 40.72%

C.4 Estimated missing pass trips (avg. weekday)
(8,993 + 19,535) x .4072 = 11,617

C.5 Turnstile average weekday pass trips
11,617 + 78,499 = 90,116

C.6 Total average weekday pass trips
Cash gate (B.14) + Turnstile (C.5)
29,876 + 90,116 = 119,992

Average Weekend Pass Trips

Steps C.3 through C.6 are repeated for estimating weekend pass trips

C.3	29,480 ÷ (29,565 + 64,650)	= 31.3%
C.4	(16,812 + 53,207) x .313	= 21,916
C.5	21,916 + 29,480	= 51,396
C.6	18,307 + 51,396	= 69,703

D. PREPAID-PASS SALES

The following table lists pass sales for the month of November and the distribution between rapid-transit and surface passes that was used in the analysis. The overlap in pass allocation occurs because certain passes can be used on both systems.

Distribution of Passes

Type of Pass[1]	Total Passes		Proportion Used on Surface		Proportion Used Rapid Transit	
	No.	Revenue	No.[2]	Revenue	No.[2]	Revenue
A $18	18,634	$ 335,412	18,634 (100.0%)	$ 335,412	-	-
B $22	36,410	801,020	4,915 (13.5%)	108,130 (13.5%)	31,495 (86.5%)	$ 692,890 (86.5%)
C $36	26,616	958,176	24,220 (91.0%)	392,852 (41.0%)	24,220 (91.0%)	479,088 (50.0%)
			1,198 (4.5%)	43,118 (4.5%)	1,198 (4.5%)	43,118 (4.5%)
D $40	4,480	179,200	2,321 (51.8%)	94,976 (53.0%)	2,321 (51.8%)	84,224 (47.0%)
			995 (22.2%)		1,165 (26.0%)	
E $48	4,800	230,400	3,456 (72.0%)	149,760 (65.0%)	3,456 (72.0%)	80,640 (35.0%)
			1,344 (28.0%)			
F $56	1,039	58,184	1,039 (100.0%)	29,092 (50.0%)	1,039 (100.0%)	29,092 (50.0%)
	91,979	$2,562,392	59,122	$1,153,340	64,894	$1,409,052

	Number	Revenue
Commutation Tickets (Express Bus & Green Line Only)	1,379	$19,312

Student Passes	Bus		Rapid Transit	
	Number	Revenue	Number	Revenue
Bus Only	7,042	$70,420		
Bus & Rapid Transit	4,000	20,000	4,000	$20,000
	11,042	$90,420	4,000	$20,000

Notes to table, Distribution of Passes:

[1]Table shows cost of pass; the maximum value per trip and the mode(s) are as follows:

A - $0.50 Surface Vehicle Only

B - $0.60 Rapid Transit (including Mattapan High-speed Line) and Streetcar

C - $1.00 Rapid Transit, Streetcar, Bus, and Express Bus

D - $1.25 Rapid Transit, Streetcar, Bus, Express Bus, and Zone 1 Commuter Rail

E - $1.50 Rapid Transit, Streetcar, Bus, Express Bus, and Zone 2 Commuter Rail

F - $1.75 All MBTA Services and Zone 3 Commuter Rail

[2]For some types of passes, two entries are given for the number of passes used on each portion of the transit system. An example is the entries for pass-type C under surface transit. The top number, 24,220, refers to the number of passes used on both surface and rapid transit, and the bottom number, 1,198, refers to the number of passes used solely on surface transit.

Passes are purchased on a monthly basis, so revenue and passes must be converted to equivalent period figures. In 1982, this was done by determining the ratio between the number of days in November and in period 11 of fiscal year 1982 (period 11 included the last two days of October through November 26). October and November figures for both pass sales and revenue were roughly equivalent in 1982. Therefore, to arrive at period-11 values, November pass sales were simply discounted by 8 percent for month-to-period conversion.

A simple 8-percent discounting was not used in 1983, because November pass sales differed from October's, by 5 percent. Rather, the portion of October days contained in period 5 of fiscal year 1983[1] was applied to sales for that month and the

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[1]In 1982 the MBTA's fiscal year was based on the calendar year. In 1983 its fiscal year was changed, and made consistent with the state's fiscal year. Period 11 of fiscal year 1982 and Period 5 of fiscal year 1983 are equivalent time periods.

portion of November days not included in period 5 was applied to November sales. November sales were adjusted by these figures to arrive at period-5 values. Student passes and revenue were simply discounted by 8 percent because they did not vary between the two months.

October weekday equivalent	=	24.00
November weekday equivalent	=	23.75
Portion of October in Period 5		
October 29-31 = 1.75		
1.75 ÷ 24	=	7.3%
Portion of November not in Period 5		
November 26-30 = 3.75		
3.75 ÷ 23.75	=	15.8%

Rapid Transit

Revenue

October revenue adjustment
1,346,944 x .073 = $98,215

November revenue adjustment
1,409,052 x .158 = $222,630

Period-5 pass revenue
1,409,052 - 222,630 + 98,215 = $1,284,637

Number of Passes

October proportion 1.75 ÷ 21.75 = .081
November proportion 20 ÷ 21.75 = .919

Period-5 passes
(64,894 x .919) + (61,992 x .081) = 64,659

Student passes
4,000 ÷ 1.08 = 3,704

Total Period 5 passes = 68,363

Surface Transit

Revenue

October revenue adjustment
1,106,170 x .073 = 80,750

November revenue adjustment
1,153,340 x .158 = 182,228

Period-5 pass revenue
1,153,340 - 182,228 + 80,750 = $1,051,862

Number of Passes

October proportion 1.75 ÷ 21.75 = .081
November proportion 20 ÷ 21.75 = .919

Period-5 passes
(59,122 x .919) + (55,633 x .081) = 58,839

Student passes
11,042 ÷ 1.08 = 10,224

Total Period-5 passes = 69,063

E. REVENUE

The revenue for Period 5, 1983, distributed to surface and rapid transit, is as follows:

E.1 Surface Revenue

Farebox revenue		$2,479,004/period
Non-farebox revenue		
Prepaid pass	$1,153,340/November $1,106,170/October	1,051,862/period[1]
Student pass	$90,400/month	83,722/period
Total Surface Revenue		$3,614,588/period

E.2 Rapid-Transit Revenue

Revenue from tokens used		$2,149,924/period
Cash-gate revenue		344,415/period
Pass revenue	$1,409,052/November $1,346,944/October	1,284,637/period[1]
Student pass	$20,000/month	18,519/period
Total Transit Revenue		$3,797,495/period

E.3 Total Revenue

$7,412,083

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[1]For the adjustment of monthly pass revenue to an accounting-period basis, see section D of these flow-diagram notes.

F. RAPID-TRANSIT TRIPS

F.1 Unlinked Rapid-Transit Trips

	1982	1983
Average Weekday		
Token trips (A.1)	155,225	157,143
Prepaid pass (C.6)	110,228	119,992
Non-pass cash gate (B.10)	70,128	70,379
Total	335,581	347,514
Average Weekend		
Token trips (A.1)	116,419	117,857
Prepaid pass (C.6)	66,980	69,703
Non-pass cash gate (B.17)	48,089	46,381
Total	231,488	233,941

F.2 Uses per Prepaid Pass

Pass Trips per Period

Avg. Weekday Pass Trips (C.6)	x	Weekday Factor	+	Avg. Weekend Pass Trips (C.6)	x	Weekend Factor
(119,999	x	18.75)	+	(69,703	x	4) = 2,528,662

Pass Trips per Period	÷	Passes Used on Rapid Transit (D)	
2,528,662	÷	68,363	= 36.99 uses per period
36.99	÷	21.75	= 1.7 uses per day

F.3 The fare mixes for unlinked rapid-transit trips representing a composite value for an average weekday and an average weekend are as follows:

	Weekday			Weekend		
Fare Mix	1981	1982	1983	1981	1982	1983
Adult						
- Cash	48.5%	49.9%	48.6%	65.4%	58.2%	62.1%
- Pass	29.2	32.3	32.3	26.2	28.9	29.8
E&H						
- Free	11.1	8.9	-	0.5	-	-
- 1/2 Fare	3.8	3.2	-	5.4	9.0	-
- Reduced	-	-	13.5	-	-	4.7
Students & Children						
- Pass	-	2.9	3.3	-	-	-
- 1/2 Fare	5.8	1.9	1.6	1.2	2.0	1.5
Free						
- Authorized	1.2	0.8	0.5	1.0	0.6	1.8
- Unauthorized	0.4	0.2	0.2	0.2	1.2	0.1
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

G. AVERAGE FARE FOR UNLINKED RAPID-TRANSIT TRIPS

Rapid-Transit Revenue ÷ Number of Rapid-Transit Trips = Average Fare

$$\text{Period 5 Revenue} \div \left[\left(\text{Average Weekday Trips}\right)\left(\text{Weekday Factor}\right) + \left(\text{Average Weekend Trips}\right)\left(\text{Weekend Factor}\right)\right] =$$

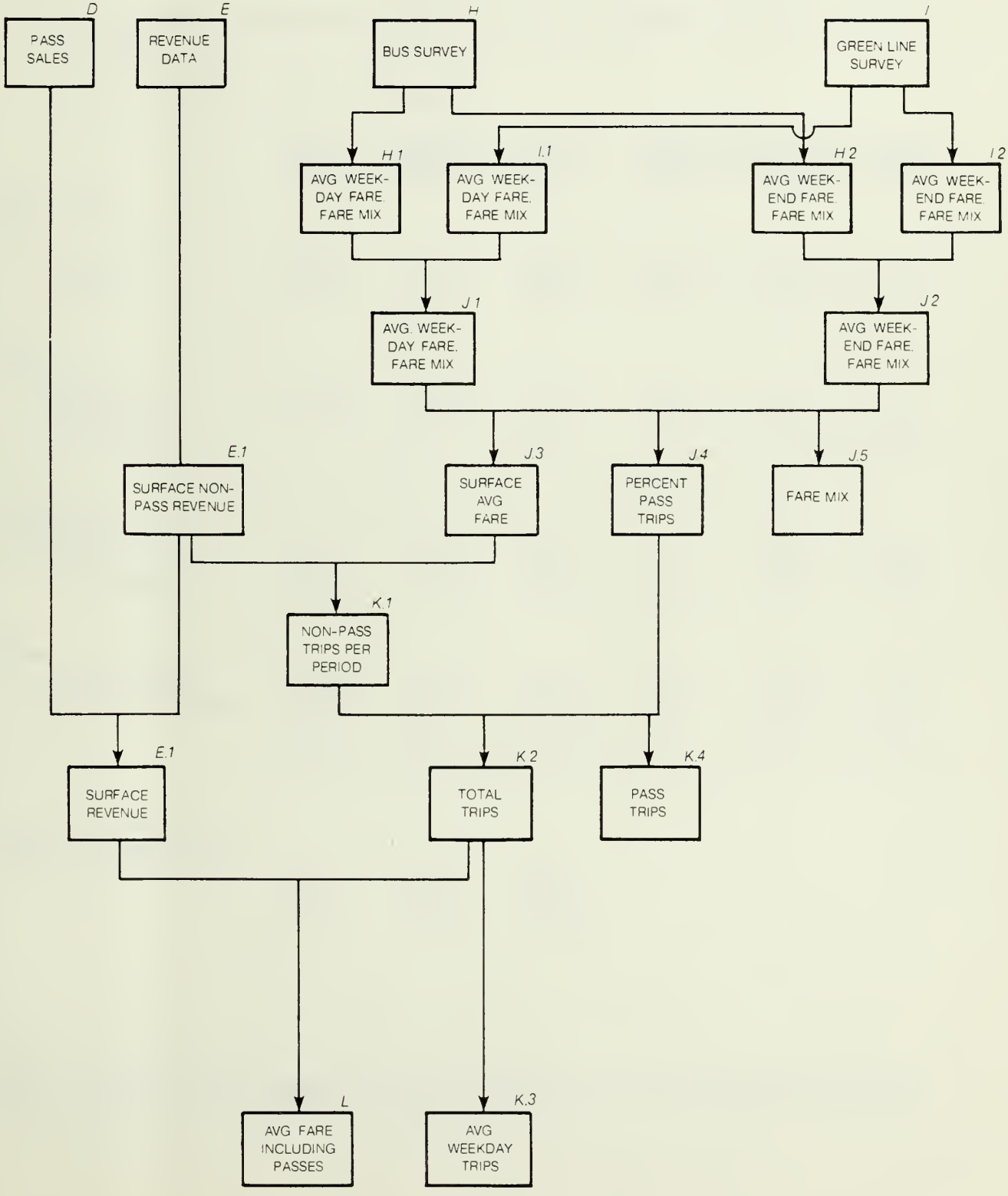
$$3{,}797{,}495 \div \left[(347{,}514)(18.75) + (233{,}941)(4)\right] =$$

$$3{,}797{,}495 \div \left[6{,}515{,}888 + 935{,}764\right] = 51.0¢$$

FLOW DIAGRAM OF 1983 FARE-MIX AND RIDERSHIP ESTIMATION

PART II

SURFACE TRANSIT



NOTES

Part II - Surface Transit/Unlinked Trips

H. BUS SURVEY

The survey conducted on the bus lines produced the following results:

H.1 Average Weekday Fare, Fare Mix

	Bus			Trackless Trolley		
Fare Mix	1981	1982	1983	1981	1982	1983
Adult						
- Cash	38.6%	35.4%	36.7%	43.1%	31.3%	37.9%
- Pass	32.1	33.9	33.1	43.0	45.1	36.5
E&H						
- Free	7.4	11.9	-	5.7	12.5	-
- 1/2 Fare	5.2	4.1	-	5.4	0.7	-
- Reduced	-	-	12.0	-	-	10.5
Students & Children						
- Pass	3.2	4.1	4.5	-	5.0	3.4
- 1/2 Fare	12.4	9.6	13.1	2.4	5.4	10.2
Free						
- Authorized	0.6	1.0	0.5	0.4	0.0	1.5
- Unauthorized	0.5	0.0	0.0	0.0	0.0	0.0
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Average fare[1] for Bus & Trackless Trolley Combined	1981	1982	1983
	40.3¢	36.3¢	39.7¢

[1]The average fare represents the weighted average by bus garage and does not include pass revenue.

H.2 Average Weekend Fare, Fare Mix[1]

	Bus		
	1981	1982	1983
Fare Mix			
Adult			
- Cash	46.5%	39.6%	46.4%
- Pass	28.4	37.0	30.4
E&H			
- Free	0.8	-	-
- 1/2 Fare	11.7	14.6	-
- Reduced	-	-	15.2
Students & Children			
- Pass	0.3	-	-
- 1/2 Fare	9.2	7.1	5.7
Free			
- Authorized	2.2	1.5	2.1
- Unauthorized	0.9	0.2	0.2
	100.0%	100.0%	100.0%
Average Fare	41.5¢	41.9¢	39.0¢

[1]Trackless trolleys do not operate on weekends.

I. GREEN LINE SURVEY

The survey conducted on the surface portion of the Green Line resulted in the following fare mix and average fare.

	I.1 Weekday			I.2 Weekend		
Fare Mix	1981	1982	1983	1981	1982	1983
Adult						
- Cash	38.4%	29.6%	31.1%	44.3%	41.6%	35.6%
- Pass	25.3	27.4	28.0	22.9	21.1	23.0
E&H						
- Free	5.9	3.6	-	0.4	-	-
- 1/2 Fare	1.6	0.9	-	4.4	4.4	-
- Reduced	-	-	7.3	-	-	5.8
Students & Children						
- Pass	0.2	0.1	0.8	-	-	-
- 1/2 Fare	1.1	1.5	1.5	1.8	1.3	1.3
Free						
- Authorized	27.0	36.9	31.2	26.2	31.4	34.3
- Unauthorized	0.0	-	0.1	-	0.2	0.1
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Average Fare[1]	41.7¢	33.7¢	37.4¢	48.2¢	45.7¢	40.4¢

[1]The average fare represents the weighted average of the four components of the surface Green Line and does not include pass revenue.

J. AVERAGE FARE AND FARE MIX (SURFACE TRANSIT)

Ridership estimates are derived for the bus and trackless-trolley systems and surface Green Line using average fares and period-5 revenue. These ridership figures are then used in weighting the average fare and fare-mix to arrive at composite estimates. The calculations for average fare and adult-pass use are given below.

Weekday	Revenue	÷ Avg. Fare	= Ridership Estimate	Proportion of Total Ridership
Bus	$85,499	÷ .398	= 214,821	.714
Trackless Trolley	$ 3,094	÷ .376	= 8,229	.027
Green Line	$29,064	÷ .374	= 77,710	.258
Weekend				
Bus	$84,543	÷ .390	= 216,776	.746
Green Line	$29,863	÷ .404	= 73,918	.254

J.1 Average Weekday Fare and Percentage Pass Use

Average Fare (.398)(.714) + (.376)(.027) + (.374)(.258) = 39.1¢
Pass (.331)(.714) + (.365)(.027) + (.28)(.258) = 31.8%

J.2 Average Weekend Fare and Percentage Pass Use

Average Fare (.39)(.746) + (.404)(.254) = 39.4¢
Pass (.304)(.746) + (.23)(.254) = 28.5%

Combining the weekday and weekend averages yields a composite average fare (J.3), pass use (J.4) and fare mix (J.5).

J.3 Average Fare

(.391)(.8696) + (.394)(.1304) = 39.1¢

J.4 Percent Pass

(.313)(.8696) + (.285)(.1304) = 31.4%

Weighted average of student-pass use = 3.1%

Total = 34.5%

J.5 Fare Mix

	Weekday and Weekend		
	1981	1982	1983
Adult			
- Cash	39.6%	34.9%	36.4%
- Pass	30.7	32.6	31.4
E&H			
- Free	6.3	8.9	-
- 1/2 Fare	5.3	4.3	-
- Reduced	-	-	11.0
Students & Children			
- Pass	2.3	2.9	3.1
- 1/2 Fare	9.9	7.4	9.3
Free			
- Authorized	5.4	9.0	8.7
- Unauthorized	0.5	-	-
	100.0%	100.0%	100.0%
Average Fare[2]	41.1¢	36.7¢	39.1¢

[1]Includes passengers riding free in the outbound direction on the surface Green Line

[2]Does not include pass revenue

K. SURFACE TRIPS

The number of unlinked average-weekday surface trips was estimated using the composite average fare and surface revenue for period 5.

Surface non-pass revenue (E.1)
less commutation-ticket revenue (D)

2,479,004 - 19,312 = 2,459,692

K.1 Non-pass Trips per Period

Revenue ÷ Non-pass avg. fare = 2,459,692 - .391 = 6,290,772

Plus ticket trips

13,794 ÷ 1.08 = 12,772 per period
6,290,772 + 12,772 = 6,303,544

K.2 Total Trips per Period

Non-pass trips ÷ Fraction of total that are non-pass

6,303,594 ÷ .655 = 9,623,731

K.3 Average Weekday Trips

Total trips ÷ Factored avg. weekdays

9,623,731 ÷ 21.75 = 442,470

K.4 Uses per Prepaid Pass

Pass trips ÷ Passes used on surface per period

(9,623,731 - 6,303,544) ÷ 69,063 = 48.1 uses per period

48.1 ÷ 21.75 = 2.2 uses per day

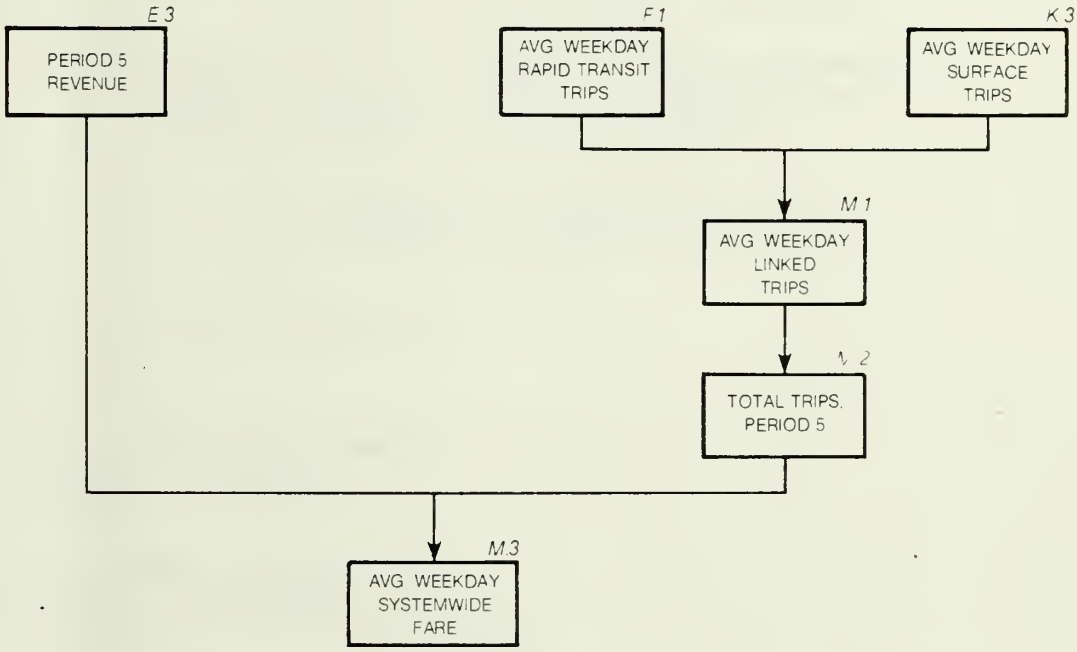
L. AVERAGE FARE FOR UNLINKED SURFACE TRIPS

Total surface revenue (E.1)	÷	Total surface trips (K.2)	
3,614,588	÷	9,623,731	= 37.6¢

FLOW DIAGRAM OF 1983 FARE-MIX AND RIDERSHIP ESTIMATION

PART III

LINKED TRIPS AND AVERAGE FARE



NOTES

Part III - Linked Trips and Average Fare

M. Average-weekday linked trips and the corresponding average fare were estimated using the following procedure:

Unlinked rapid-transit trips = 347,514
Unlinked surface trips = 442,470

Rapid transit only = X (29%)
Combination = Y (40%)
Surface only = Z (31%)
(Percentages from 1978 Systemwide Survey)

$X + Y = 347,514$ $(X = 347,514 - Y)$
$Z + Y = 442,470$ $(Z = 442,470 - Y)$
$Y \div (X + Y + Z) = .40$

Solving the third equation:

$Y = 225,710$

X = (unlinked rapid-transit trips) - Y
= 347,514 - 225,710
= 121,804

Z = (unlinked surface trips) - Y
= 442,470 - 225,710
= 216,760
15% of these trips are surface-to-surface transfers
= 216,760 x .85
= 184,246

M.1 X + Y + Z = total linked trips/weekday
121,804 + 184,246 + 225,710 = 531,760

M.2 Weekday linked trips x period factor = linked trips/period
531,760 x 21.75 = 11,565,780

M.3 Average fare
$7,412,083 ÷ 11,565,780 = 64.1¢

Total unlinked trips per period
442,470 + 347,514 = 789,984
(K.3) (F.1)

APPENDIX 2

Survey Samples and Schedules

TABLE A-2a

SURFACE GREEN LINE SURVEY SCHEDULE

Branch	Valid Trips	Trips Required	Date(s)
Weekday			
Boston College	26	10	11/18, 11/21-22
Cleveland Circle	18	8	11/18, 11/22
Riverside	22	9	11/18, 11/21-22
Arborway	18	7	11/18, 11/21-22
Weekend			
Boston College	30	12	11/20, 12/3, 12/10
Cleveland Circle	24	9	11/20, 12/3, 12/10
Riverside	24	11	11/20, 12/3, 12/10
Arborway	22	9	11/20, 11/3, 12/10

TABLE A-2b

RUNS SAMPLED PER GARAGE

Garage	Total Weekday Runs	Runs Sampled
Cabot	214	6
Arborway	140	5
Salem	198	6
Somerville	138	5
Lynn	107	4
Quincy	88	3
Bennett*	32	2
	917	31

Garage	Total Weekend Runs	Runs Sampled
Cabot	136	3
Arborway	108	3
Salem	142	3
Somerville	122	3
Lynn	84	3
Quincy	72	3
	664	18

*Trackless trolley

TABLE A-2c, p.1

BUS AND TRACKLESS-TROLLEY SURVEY SCHEDULE

Day of Week	District	Run Number[1]	Date of Count
Weekday	Cabot	1013	11/4
		1109	11/4
		1151	11/4
		1515	11/4
		1533	11/4
		9030	11/14
	Arborway	1054	11/14
		1069	11/14
		1102	11/14
		1106	11/14
		9002	11/14
	Salem	104	11/16
		114	11/16
		1024	11/16
		1055	11/16
		1073	11/16
		1091	11/16
	Somerville	1010	11/15
		1023	11/15
		1070	11/15
		1099	11/15
		9018	11/15
	Lynn	1005	11/17
		1007	11/17
		1047	11/17
		1305	11/17
	Quincy	1005	11/17
		1029	11/17
		9025	11/17
	Bennett[2]	1509	11/15
		1510	11/15

[1]Any run that has a run number starting with a 9 is handled by a part-time driver.

[2]Trackless trolley

TABLE A-2c, p.2

BUS AND TRACKLESS-TROLLEY SURVEY SCHEDULE

Day of Week	District	Run Number	Date of Count
Saturday	Cabot	2042	11/5
		2128	11/5
	Arborway	2018	11/19
		2019	11/19
	Salem	2011	11/5
		2402	11/19
	Somerville	2003	11/5
		2070	11/19
	Quincy	2016	11/5
		2021	11/5
	Lynn	2009	11/19
		2036	11/19
Sunday	Cabot	3056	11/6
	Arborway	3015	11/6
	Salem	3025	11/6
	Somerville	3008	11/6
	Quincy	3015	11/6
	Lynn	3015	11/6

TABLE A-2d

RAPID-TRANSIT COUNT
COLLECTOR'S-TURNSTILE SAMPLE

WEEKDAY (22)[1]

6 AM - 10 AM (8)
- Lechmere
- Wonderland
- Orient Heights
- Malden
- Shawmut
- Central Square
- North Quincy
- Copley

3 PM - 6 PM (5)
- Government Center
- Maverick
- Sullivan
- Park Under
- Haymarket - Green

11 AM - 2 PM (6)
- Dover
- Auditorium
- Malden
- State - Blue
- North Station
- Quincy Center

6 PM - 10 PM (3)
- Essex
- Government Center
- Sullivan

WEEKEND (22)

Saturday (10)

6 AM - 10 PM (3)
- Sullivan
- Wollaston
- State - Blue

10 AM - 2 PM (4)
- Malden
- Airport
- Auditorium
- Arlington

2 PM - 6 PM (3)
- Harvard
- North Quincy
- Northampton

Sunday (12)

6 AM - 10 AM (4)
- Egleston
- So. Braintree
- Airport
- Canal - North Station

10 AM - 2 PM (4)
- Oak Grove
- Dudley
- Arlington
- Government Center

2 PM - 6 PM (4)
- North Quincy
- Copley
- Washington - Red
- Haymarket - Green

---

[1]Numbers in parentheses indicate number of stations at which collector's turnstiles were sampled during each time period.

TABLE A-2e

RAPID-TRANSIT STATIONS
GATEMAN ASSIGNMENTS

Stations	Gateman Hours	Total Hours
Washington - North	11:00 AM - 7:00 PM	8
Dudley	7:00 AM - 10:00 AM	3
	11:00 AM - 3:45 PM	4.75
Egleston	6:30 AM - 9:00 AM	2.5
	11:00 AM - 3:00 PM	4
Forest Hills	6:30 AM - 9:30 AM	3
Harvard/Brattle	6:15 AM - 2:00 PM	7.75
	2:00 PM - 8:00 PM	6
Andrew	6:30 AM - 9:30 AM	3
	12:30 PM - 3:30 PM	3
Fields Corner	6:30 AM - 9:30 AM	3
	12:30 PM - 3:30 PM	3
Ashmont	6:30 AM - 9:30 AM	3
	12:30 PM - 3:30 PM	3

APPENDIX 3

Pass Usage

TABLE A-3a

AVERAGE WEEKDAY PASS USAGE
ON SURFACE TRANSIT BY GARAGE

Arborway	12.1%
Cabot	22.4
Salem	13.3
Somerville	9.9
Lynn	7.3
Quincy	6.8
Bennett*	2.3
Green Line	25.9
	100.0%

*Trackless trolley

TABLE A-3b

AVERAGE WEEKDAY PASS USAGE
BY RAPID-TRANSIT LINE

Orange Line	28.6%
Red Line[1]	24.0
Red Line South Shore Extension	4.4
Blue Line	6.1
Green Line[2]	36.9
	100.0%

---

[1]Does not include North Quincy and stations outbound therefrom (for which, see Red Line South Shore Extension)

[2]Does not include surface portion

APPENDIX 4

Survey Forms

FARE MIX AND RIDERSHIP CHARACTERISTICS
RAPID TRANSIT STATION SURVEY FORM (COLLECTOR'S TURNSTYLE)

NAME		STATION	
DATE		ENTRANCE	
DAY OF WEEK		START TIME	O AM O PM

PASSENGER COUNTING

TIME PERIOD					
E & H	REDUCED FARE				
STUDENTS & CHILDREN	HALF FARE				
	PASS				
ADULTS	CASH FARE				
	PASS				
OTHER FREE	AUTHORIZED				
	NON AUTHORIZED				

PASSENGER READING

READING	BEGIN:	READING	END:

FARE BOX AND METER READINGS

CASH	BEGIN:	CASH	END:
PENNY	BEGIN:	PENNY	END:
TOKEN	BEGIN:	TOKEN	END:
TURNSTYLE METER	BEGIN:	TURNSTYLE METER	END:

Fare Mix and Ridership Characteristics

Rapid Transit Station Survey Form (Gate w/ Attendants)

Name		Station	
Date		Entrance	
Day of the Week		Start Time	○ A.M. ○ P.M.

Passenger Counting

Time Period	Prepaid Pass	Full Fare	Other	Total

Passenger Reading if Any

Reading	Begin:	End:

Fare Box Reading

Cash	Begin:	End:
Penny	Begin:	End:
Token	Begin:	End:

Remarks

FARE MIX AND RIDERSHIP CHARACTERISTICS
BUS SURVEY FORM

NAME		DATE	1 2 3 4 5
GARAGE	6 7	BUS #	8 9 10 11
RUN #	12 13 14 15	ROUTE #	16 17 18
DIRECTION	O INBOUND O OUTBOUND — 19	SCHEDULED START TIME	O AM O PM — 20 21 22 23
ACTUAL START TIME	O AM O PM — 24 25 26 27	ACTUAL ARRIV TIME	O AM O PM — 28 29 30 31

PASSENGER COUNTING

ADULT	CASH FARE	32 33 34
	PASS	35 36 37
E & H	REDUCED FARE	38 39
STUDENT & CHILDREN	HALF FARE	40 41
	PASS	42 43
OTHER FREE	AUTHORIZED	44 45
	NON AUTHORIZED	46 47

FARE BOX READING

CASH	BEGIN:	48 49 50 51 52	CASH	END:	53 54 55 56 57
PENNY	BEGIN:	58 59 60 61 62	PENNY	END:	63 64 65 66 67
TOKEN	BEGIN:	68 69 70 71 72	TOKEN	END:	73 74 75 76 77
$ BILLS					78 79 80

FARE MIX AND RIDERSHIP CHARACTERISTICS
GREEN LINE SURVEY FORM

NAME					DATE		1	2	3	4	5
CAR HOUSE				6	VEHICLE #			7	8	9	10
ROUTE #		11	12	13	DIRECTION	O INBOUND O OUTBOUND					14
START TIME	A.M. P.M.	15	16	17	18						

PASSENGER COUNTING

ADULT	CASH FARE		19	20	21
	PASS		22	23	24
E & H	REDUCED FARE		25	26	27
STUDENT & CHILDREN	1/2 FARE		28	29	30
	PASS		31	32	33
OTHER FREE	AUTHORIZED		34	35	36
	NON AUTHORIZED		37	38	39

PORTAL LOAD COUNT

# ONBOARD AFTER LAST ABOVE GROUND STOP INBOUND		40	41	42	# ONBOARD AFTER LAST BELOW GROUND STOP OUTBOUND		43	44	45

FARE BOX READING

CASH	BEGIN:	46	47	48	49	50	CASH	END:	51	52	53	54	55
PENNY	BEGIN:	56	57	58	59	60	PENNY	END:	61	62	63	64	65
TOKEN	BEGIN:	66	67	68	69	70	TOKEN	END:	71	72	73	74	75
$ BILLS RECEIVED DURING TRIP									76	77	78		

MASS. MP03.2: M45/2/984

CTPS TECHNICAL REPORT 55

1984 MBTA FARE-MIX SAMPLING PROGRAM: ANALYSIS AND DOCUMENTATION

870258 ★ JUN 15 87

June 1986

CTPS TECHNICAL REPORT 55

TITLE 1984 MBTA Fare-Mix Sampling Program: Analysis and Documentation

AUTHOR(S) Mary Ellen Sullivan
Alicia Powell Wilson

DATE June 1986

ABSTRACT This report describes the assumptions and methods used to design and administer a sampling program to determine the fare mix and average fare for rapid transit, buses, and the surface Green Line. The information obtained from this program was used in conjunction with revenue data to determine the number of unlinked and linked trips made on rapid-transit and surface routes in November 1984.

This document was prepared by **CENTRAL TRANSPORTATION PLANNING STAFF**, an interagency transportation planning staff created and directed by the Metropolitan Planning Organization, consisting of the member agencies.

Executive Office of Transportation and Construction
Massachusetts Bay Transportation Authority
Massachusetts Department of Public Works
MBTA Advisory Board
Massachusetts Port Authority
Metropolitan Area Planning Council

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This document was prepared in cooperation with the Urban Mass Transportation Administration of the U. S. Department of Transportation through the technical study grant(s) cited below, and was also financed with state and local matching funds.

MA-09-0107
MA-08-0115
MA-08-0126

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ACKNOWLEDGMENTS

The sampling program used this year and previous years was designed and developed with the invaluable assistance of Alan Castaline and other MBTA personnel. The formidable task of data collection was performed by the MBTA traffic checkers.

1 INTRODUCTION

Historically, the MBTA has estimated daily and annual ridership by dividing collected revenue by an average fare. In 1981 it was decided that, because of various fare and system changes, the average-fare figure being used was no longer valid. In addition, accurate data were needed to develop pricing and marketing policies and to satisfy federal reporting requirements.

Therefore, in November of 1981, the MBTA instituted a new program for estimating ridership whereby the average fare used to calculate the number of riders from revenue is determined by surveying a sample of actual ridership. The number of passengers boarding, the type of fare they paid, and farebox revenue are recorded for selected bus routes, on the surface portions of the Green Line, and at selected rapid-transit stations. The resulting data are processed and analyzed by the Central Transportation Planning Staff (CTPS).

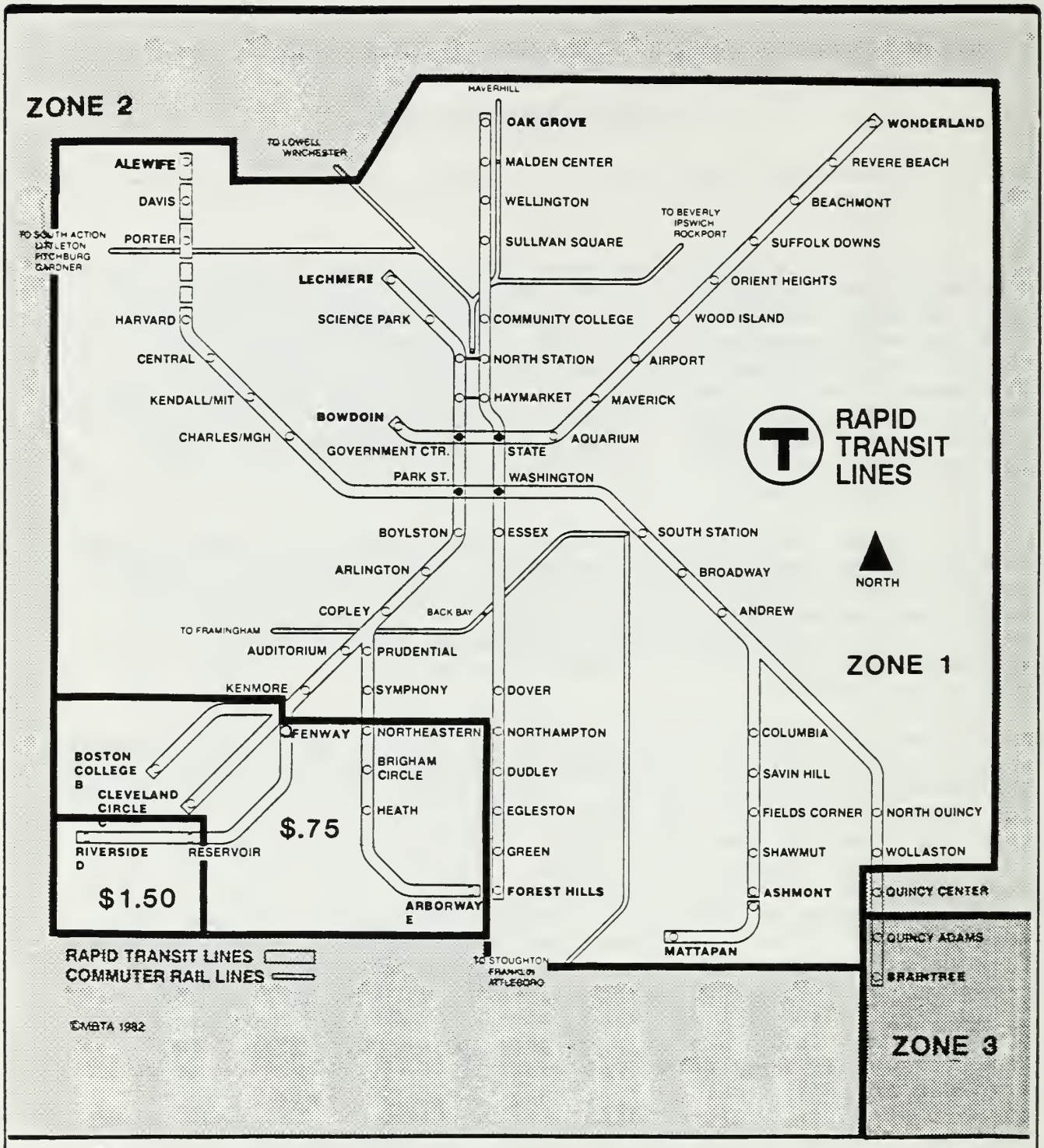
This report presents the 1984 survey results and analysis procedures and the three previous years' results. The analyses, as well as the results, of the 1981, 1982, and 1983 fare-mix surveys are available in CTPS Technical Reports 39, 43, and 48, respectively.

2 MBTA TRANSIT SERVICE

As of 1984, when the new data for this report were collected, the MBTA operated public transit on three rapid-transit lines (Red, Orange, and Blue), five light-rail branches (the Green Line and the Mattapan high-speed line), trackless-trolley routes, bus routes, and commuter-rail lines (not covered in this report). The Green Line is a combination of low-platform streetcar service on the surface and rapid-transit or subway service in the downtown and Back Bay areas. Figure 2-1 is a map of the transit system, showing fares by zone; Table 2-1 presents the fare tariff for the bus system.

The basic adult cash fares are sixty cents for rapid transit and for subway Green Line service and fifty cents for trackless-trolley and local bus service. There are zoned fares on some local bus routes and a range of fares on express-bus routes. Fares on the surface portion of the Green Line are paid in the inbound direction only and range from seventy-five cents to a dollar and a half.

Riders can also purchase a variety of pre-paid monthly passes which have no limit on the number of times that they can be used. The elderly (65 and over) pay a ten-cent fare at all times except for express and zoned bus trips beyond the local area, for which they pay one-half the adult fare. The handicapped pay the full adult fare for peak-period travel (7:00-9:00 A.M. and 4:00-6:00 P.M. weekdays) and the elderly fare at all other times. In 1986 this was changed so that the elderly fare applies to the handicapped at all times. Children between five and twelve pay half-fare at all times. Students in kingergarten through twelfth grade pay half-fare during school hours if they have proper identification. Students can also obtain monthly passes from their schools. All fares are paid as passengers board buses and trolleys and as they enter rapid-transit stations. Passengers also pay an additional fare as they leave the Zone 3 rapid-transit stations (Quincy Adams and Braintree). In rapid-transit stations, tokens are deposited before passengers pass through the regular, full-fare turnstiles. At least two turnstiles per station are equipped to read electronically the pre-paid passes (not including student passes). Those who pay reduced fares or no fare are supposed to use turnstiles at the collector's booths (referred to as collector's turnstiles in this report). "Gateman's boxes," which allow passengers paying any type of fare to pass through, are open in several stations (primarily at peak travel times).



	ADULT	STUDENT & CHILDREN	ELDERLY
ZONE 1	$.60	$.30	$.10
ZONE 2	$.90	$.45	$.10
ZONE 3	$1.20	$.60	$.10

1984 MBTA Fare-Mix Sampling Program	RAPID-TRANSIT NETWORK AND ZONAL FARES (1984)	CTPS FIGURE 2-1
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Zone	Route Miles*	Adult Fare**	Student & Child Fare	Elderly Fare
1	0 - 6	$0.50	$ .25	$ .10
2	6 - 9	0.75	.35	$ .35
3	9 - 12	1.00	.50	.50
4	12 - 15	1.25	.60	.60
5	15+	1.50	.75	.75

*Zone fares may be adjusted based on geographic, topographic, or other distinctive circumstances in order to establish logical boundaries.

**NOTES ON ADULT FARE:

- o Base Fare - $0.50, good for all routes that are less than 6 miles and for the first 6-mile zone on routes longer than 6 miles.
- o Zone Fares - Additional $0.25 for each 3-mile increment.
- o Express Premium - Additional $0.25 for express-bus services.
- o Maximum Fare - $1.50, including express premium.

1984 MBTA Fare-Mix Sampling Program	BUS-SYSTEM ZONAL FARE TARIFF (1984)	CTPS TABLE 2-1
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3 TRANSIT-SERVICE AND -FARE CHANGES BETWEEN 1981 and 1984

It is important to realize that apparent increases or decreases in transit ridership between 1981, 1982, 1983, and 1984 in several categories can, in part, be attributed to transit-service or -fare changes. For example, in December 1982, the revoking of the elderly-and-handicapped off-peak free fare had an impact on surface-transit ridership. In addition, refinements to survey and data-analysis techniques have influenced survey results. Attempts have been made in this section and the next to point out these differences and how they affect the data.

3.1 SERVICE CHANGES

3.1.1 1981-1983

In November 1981, when the first fare-mix survey was conducted, the Dorchester Branch of the Red Line (between Columbia and Ashmont stations) and the Mattapan High-Speed Line were not in service because new track was being laid. The people who normally used these portions of the system were bused to Andrew or North Quincy stations. The token turnstiles at these stations, particularly Andrew, were not designed to handle the increased passenger load during the A.M. and P.M. peaks. Therefore, many of those who used tokens and prepaid passes, as well as those who paid cash, went through the collectors' turnstiles and the open gates that were monitored by gatemen. This resulted in uncharacteristically high figures for usage of the collectors' turnstiles and gatemen's boxes. It should also be pointed out that the 1981 sample did not include those who made local trips on the substitute bus service for the Dorchester Branch.

The Arborway Branch of the Green Line was also not in operation during November 1981. Inbound Arborway users were bused to Copley Station, where they went through gates without paying an additional fare, thereby influencing gate counts at Copley. Service was restored on this branch in June 1982. The addition of Arborway riders in the 1982 sample of the surface Green Line influenced the average fare for the Green Line.

Rapid-transit service in 1983 was the same as in 1982, with two exceptions. On September 3, 1983, Quincy Adams Station opened. This station is located between Quincy Center and Braintree stations on the southern extension of the Red Line.

At the other end of the Red Line, the Harvard/Brattle and Harvard/Holyoke stations were closed in September 1983, and all passengers began using Harvard Station. On surface transit, a few new routes were added and some changes were made to existing routes between 1982 and 1983; overall, these changes did not alter the character of the system.

3.1.2 1984

Rapid-transit service and surface-transit service remained essentially the same in 1984. While Porter and Davis stations were opened in December 1984, the openings took place after the close of the sampling period.

3.2 FARE CHANGES

3.2.1 1981-1983

The base rapid-transit fare was seventy-five cents in November 1981. It was reduced to sixty cents in May 1982. Student passes were available only for bus trips during 1981. Boston public-school students who used rapid transit were issued tokens at thirty-five cents apiece. Beginning in September 1982, student passes were available, which could be used on either mode. The base fare for surface transit did not change between 1981 and 1982.

The basic adult fare for surface transit and rapid transit did not change from 1982 to 1983. The free off-peak elderly fare (9:30 A.M.-4:00 P.M., Monday-Friday), with half-fare for the elderly at all other times, was replaced by a ten-cent fare at all times, except for express bus, zoned bus beyond the local area, and commuter rail. This fare change resulted from a bill passed by the legislature that became effective on December 20, 1982.

3.2.2 1984

There were no fare changes for surface transit or rapid transit in any category during 1984.

4 SAMPLING TECHNIQUES AND DATA-COLLECTION PROCEDURES

4.1 OVERVIEW

Ridership is estimated from revenue using an average fare determined from the fare mix. The sampling program was designed to find the fare mix. Sampling techniques for 1984 surface transit are essentially the same as those used in past years. Rapid-transit service was not sampled in 1984, however, because the relatively small variation in fare mix between 1982 and 1983 indicated that a new sample was not warranted. Instead, 1983 survey results were applied to 1984 revenue data to estimate ridership for 1984. A summary of the techniques is provided below.

The average fare can be calculated as follows:

$$F_a = (F_f \times P_f) + (F_r \times P_r)$$

where F_a = average fare
F_f = full fare
F_r = reduced fare
P_f = % passengers who pay full fare
P_r = % passengers who pay reduced fare

The degree of precision or confidence interval of the average fare can be calculated as follows:

$$\pm [CIP_f \times F_f + (CIP_r \times F_r)]$$

where CIP = confidence interval of the fare mix (P_f and P_r, respectively)

For the purposes of the sampling program, the confidence interval of the fare mix was set at $\pm$2.5 percent and the confidence level (allowable degree of risk) at 95 percent. These parameters mean that the probability of the estimated fare mix differing by more than 2.5 percent from the actual fare mix is one in twenty.

To determine the fare mix, the least complicated sampling technique available was the simple random sample, wherein each item or individual had an equal chance of being selected. The number of observations (or the size) for this type of sample is determined by the confidence interval, the confidence level, and the nature of the results required (in this connection, seen in terms of proportions of riders). The formula used to calculate the sample size was the following:

$$No = pq \frac{t^2}{d^2}$$

where No = the required sample size
p = the unknown proportion
q = the remaining proportion
d = the interval size
t = the statistic which relates the confidence level to the normal curve

The "unknown" and "remaining" proportions correspond, respectively, to the percentage of riders who pay full adult fare and the percentage who pay other than full fare. For the purpose of calculating sample size, these proportions were estimated to be fifty/fifty, which produced the largest possible proportions. (Note that of all possible proportions, fifty/fifty is always most conducive to a large sample size.) Using the given parameters, the formula yields a sample size of 1,536, which was rounded to 1,540.

After the sampling program was completed, actual confidence intervals obtained were calculated by using the formula

$$\pm \; a \sqrt{\frac{P_s Q_s}{N}}$$

where a = coefficient of confidence level
P_s = sampling proportion
Q_s = the remaining proportion
N = the number of observations

For example, if 1,600 passengers were counted and the following data were obtained:

Fare mix - Full fare = 65% (P_f)
Reduced fare = 25% (P_r)
Free = 10%

Fare - Full fare = 60¢
Reduced fare = 30¢

then the confidence interval of the fare mix at a 95-percent confidence level would be:

$$\underline{\text{Full fare}} = 1.96 \times \sqrt{\frac{.65(.35)}{1,600}} = \pm 2.34\%$$

or 65% $\pm$ 2.34% = 62.66% to 67.34%

$$\underline{\text{Reduced fare}} = \pm 1.96 \times \sqrt{\frac{.25(.75)}{1,600}} = \pm 2.12\%$$

or 25% $\pm$ 2.12% = 22.88% to 27.12%

The average fare would be:

$$(60¢ \times .65) + (30¢ \times .25) = 46.5¢$$

and the confidence interval of the average fare would be:

$$(.0234 \times .60) + (.0212 \times .30) = 2.04¢$$

$$\text{or } 46.5¢ \pm 2.04¢ = 44.5¢ \text{ to } 48.5¢$$

4.2 SURFACE TRANSIT (BUS, TRACKLESS TROLLEY, AND SURFACE GREEN LINE)

4.2.1 Bus and Trackless Trolley, 1981-1983

Surface-transit revenue is calculated by district; therefore, a sample was drawn from each one. Within a given district, a driver's daily duty assignment is called a "run," which includes trips on one or several routes. It was decided that the bus-and-trackless-trolley sample should be based on runs, since the people doing the counts could then be assigned to a driver for a day and not have to worry about making connections with other vehicles. Note that the use of runs may not always insure an unbiased estimate for the population as a whole; however, given constraints on time and resources, it is the most efficient method available.

The number of runs sampled per district was pro-rated according to the proportion of district runs to total runs. The resulting number of runs to be sampled per district ranged from 2 to 12 for the weekday sample and from 3 to 5 for the weekend sample in 1982. (The total number of runs sampled was determined through estimating the average number of passengers per trip.) In 1983, because of manpower constraints during November, it was necessary to reduce the number of runs sampled. This could be done without a loss in statistical significance, since four out of the seven districts were over-sampled in 1982. Results were weighted according to the number of daily scheduled runs by district. The number of sampled runs per district ranged from two to six, for a total of 30 runs--compared to 41 for 1982. Two runs from each district were sampled on Saturday and one run on Sunday. All runs for each year were listed by district and the selections were made by using a random-numbers table.

Only one traffic checker per run was needed to collect data for the bus-and-trackless-trolley sample. He sat behind the driver and recorded the number of people boarding and the type of fare paid (adult full-fare, student pass, etc.), farebox readings, and other pertinent information.

4.2.2 Bus and Trackless Trolley, 1984

As in previous years, the sample selection was based on driver runs. Since the reduced sample size (30 runs) produced

reliable results in 1983, approximately the same number of runs (32) was sampled in 1984. An additional two runs were sampled in response to the recommendation that samples from the smaller districts be increased. The number of sampled runs by district varied only slightly from 1983, ranging from 3 to 6 runs per district. As in the 1983 weekend sampling program, two runs from each district were sampled on Saturday and one run per district was sampled on Sunday. Again, the results were weighted according to the number of scheduled runs by district. These runs were selected by using a random-numbers table (Table A-2a in Appendix 2 lists the selected runs).

4.2.3 Surface Green Line, 1981-1983

For the surface Green Line, in 1981, a simple random sample of runs was selected at the Reservoir Garage, from which Green Line cars are dispatched. Traffic checkers were assigned to specific runs, which meant that they had to stay on a particular car until their shifts ended. They counted people boarding inbound on the surface portion, recorded the type of fare paid, and recorded surface revenue; then they rode underground to the end of the line, rode back in the outbound direction, and counted people boarding outbound on the surface (no fares are collected). Among the problems encountered were frequent farebox malfunctions, which meant that sometimes there was no revenue figure (and therefore no average fare) for an entire run. The procedure was confusing to the checkers and they frequently failed to count those boarding in the outbound direction. Even though a portion of the survey was conducted a second time, some faulty data were still obtained.

In 1982, it was decided that the sample of the surface Green Line should be based on trips instead of runs. The 1978 system-wide survey was used to determine the minimum number of inbound trips that had to be surveyed per time period, by branch. The same number of outbound trips per period also had to be surveyed. The first A.M. inbound trip to be boarded by a given checker on a given survey day was selected randomly (from trips before 6:05 A.M.). The checker rode in on that trip, got off at Kenmore (Symphony on the Arborway branch), and got on the next outbound car on the branch to which he had been assigned. Therefore, if a car had a faulty farebox meter, only one, rather than a series, of surveyed trips had unusable data. The 1982 outbound count was much more accurate than that of 1981. Although the data show an increase in outbound ridership, the nature of the changes between the two years is unclear, given the inaccuracy of the 1981 data.

The surface 1983 Green Line survey was conducted in a manner similar to that of 1982. Once again, it was necessary to reduce the number of trips sampled. The inbound starting time for a given checker was the same as in 1982. After riding in on that trip and disembarking at Kenmore, a checker could then get on the next outbound car on any line. Results were weighted based on the number of scheduled trips per line.

4.2.4 Surface Green Line, 1984

The method for the 1984 surface Green Line survey remained the same as in 1983, with more trips surveyed than in 1983. A total of 96 weekday trips were sampled in 1984--compared to 84 in 1983. Corresponding weekend trips were 108 in 1984 and 100 in 1983. The variation in the number of surveyed trips resulted from the necessity of maintaining the appropriate number of trips per line by time of day (see Table 4-1). Again, the results were weighted according to the number of scheduled trips per line. Table A-2b in Appendix 2 shows the surface Green Line schedule in detail.

4.3 RAPID TRANSIT

4.3.1 1981-1983

At rapid-transit stations, only collector's turnstiles and gateman's boxes required manual counting. The regular turnstiles, when functioning properly, provide the necessary data on token and prepaid-pass usage. Traffic checkers recorded the number of people passing the gateman's box, by method of fare payment. They recorded turnstile readings at the collector's turnstiles (and at the regular turnstiles, as a back-up to the data provided by the MBTA).

During an average weekday, 13 percent of all rapid-transit users passed through collector's turnstiles at 54 stations. For each station, the proportions of riders using the collector's turnstile to total riders system-wide using the collector's turnstile, in each of four time periods, were calculated. These proportions were listed in a table on a station-by-time-period basis and organized into four groups, three of which represented roughly equal percentages of the total. Only a minor proportion of passengers was accounted for in the fourth group; therefore, it was decided that it would be inefficient to sample that group. It was initially determined that 1,500 passengers should be sampled from each group, but, when the fourth group was eliminated, the sample size was increased for each of the other groups, and cells were drawn from the first, second, and third groups equally.

In 1982, as in 1981, a relatively small number of rapid-transit stations had gateman's boxes that were authorized to be open, so all of these were counted. However, it was discovered that gates at many stations were open unofficially. Therefore, a random sample of these was selected for counting.

The number of rapid-transit stations at which collector's turnstiles were sampled was reduced from 29 to 23. The starting point for making the selection was 1982 station choices. Stations were deleted so as to maintain a sample representative of the three station groups described above in this section.

DISTRIBUTION OF INBOUND SURFACE-GREEN-LINE BOARDINGS BY BRANCH AND TIME PERIOD*

	Riverside	Boston College	Cleveland Circle
6:00-9:00 A.M.	36.0%	27.2%	35.8%
9:00-3:00 P.M.	36.1	46.6	42.0
3:00-6:00 P.M.	21.3	20.5	16.5
6:00-Midnight	6.6	5.7	5.8
Total	100.0%	100.0%	100.1%

MINIMUM INBOUND TRIPS TO BE SURVEYED PER PERIOD**

	Riverside	Boston College	Cleveland Circle	Arborway
6:00-9:00 A.M.	3	3	3	2
9:00-3:00 P.M.	3	4	3	3
3:00-6:00 P.M.	2	2	1	1
6:00-Midnight	1	1	1	1
Total	9	10	8	7

*Source: 1978 Systemwide Survey

**Arborway was not surveyed in 1978; however, it was felt that the Arborway ridership profile closely resembles that of the Cleveland Circle Branch.

1984 MBTA Fare-Mix Sampling Program	SURFACE GREEN LINE DISTRIBUTION OF BOARDINGS AND OF SURVEYED TRIPS	CTPS TABLE 4-1
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Gateman's boxes at rapid-transit stations were also sampled. No sample was taken at unofficial gates in 1983; 1982 survey results were used for this component of the analysis.

4.3.2 1984

Collector's turnstiles and gatemen's boxes were not surveyed in 1984. Given the slight variation in fare mix and average fare between 1982 and 1983 and the existing constraints on time and personnel, it was decided that a rapid-transit survey need only be conducted every other year and that average fare and fare mix could be assumed to be the same in 1984 as in 1983.

5 DATA-ANALYSIS PROCEDURES AND RESULTS

The following discussion summarizes the data analysis and results of the Fare-Mix Sampling Program for unlinked and linked trips. A more detailed explanation of the data-analysis procedures is given in Appendix 1.

For the purpose of this survey, an unlinked surface trip is defined as a trip made using one surface vehicle, and an unlinked rapid-transit trip is defined as a trip made on the rapid-transit system (including the underground portion of the Green Line) and can include transfers from one rail-transit line to another. A linked trip is defined as one trip from origin to destination that includes a transfer between surface and rapid transit. For example, if one were to ride a bus from near one's home to a rapid-transit station and there board the subway for the remainder of the trip to work, one linked trip would be the result.

5.1 UNLINKED TRIPS

5.1.1 Surface Transit (Surface Green Line, Buses, and Trackless Trolleys)

o Data-Analysis Procedure

The data used to estimate the average fare were obtained from a survey of the surface portions of the Green Line and selected bus and trackless-trolley routes. Traffic checkers counted passengers and recorded their method of fare payment and the fare-box readings.

o Results

In Table 5-1 the fare mix and average fare for the surface portion of the Green Line are presented. Between the 1981 and 1982 survey periods, the average fare decreased by 8¢, from 41.7¢ to 33.7¢. In 1983, the average fare was 37.4¢, 3.7¢ higher than in the 1982 survey period. In 1984, the average fare increased by 3.2¢, from 37.4¢ to 40.6¢.

Noteworthy among the changes in the fare-mix proportions are those in the authorized-free component. In the 1982 survey period, this category accounts for almost 37 percent of all use, while the corresponding figures for 1981 and 1983 are 27 percent and 31.2 percent, respectively. While the 1982 proportion does not appear consistent with the survey results of 1981 and 1983, it is more consistent with the 1984 proportion of 34.4 percent.

		1981	1982	1983	1984
Fare Mix					
Adult	- Cash	38.4%	29.6%	31.1%	31.9%
	- Pass	25.3	27.4	28.0	27.7
Elderly & Handicapped	- Free	5.9	3.6	-	-
	- 1/2 Fare	1.6	0.9	-	-
	- Reduced	-	-	7.3	4.1
Students & Children	- 1/2 Fare	1.1	1.5	1.5	1.2
	- Pass	0.2	0.1	0.8	0.8
Free	- Authorized	27.0	36.9	31.2	34.3
	- Unauthorized	0.0	-	0.1	0.0
		100.0%	100.0%	100.0%	100.0%
Average Fare[1]		41.7¢	33.7¢	37.4¢	40.6¢
Confidence Interval of Average Fare					
		N.A.	±1.0¢	±1.2¢	±1.5¢

[1]The average fare represents the weighted average of the four components of the surface Green Line and does not include pass revenue.

1984 MBTA Fare-Mix Sampling Program Technical Report 55 June 1986	SURFACE-GREEN-LINE FARE MIX 1981-1984 (WEEKDAY)	CTPS TABLE 5-1

The bus and trackless-trolley fare mix and average fare are presented by bus garage in Table 5-2 and summarized by year in Table 5-3. Among the four survey periods there are significant fluctuations in fare-category proportions and average fares. From 1981 to 1982, pass use increased for all but two garages, as did the proportion of elderly and handicapped who paid no fare. Several garages had substantial increases in the latter category. In contrast, between 1982 and 1983, there are decreases in the proportion of all elderly and handicapped users for four out of the seven garages. In 1984, the elderly and handicapped proportion of users showed marked changes--both increases and decreases--in all but two garages, and prepaid-pass use increased in all but one garage.

The year-to-year variations among the garages in the elderly-and-handicapped and student categories are the result of the random selection of runs that vary in service to elderly housing complexes and to schools. Despite the broad fluctuations at the garage level, Table 5-3 shows that the overall historical fluctuations in fare mix are relatively consistent, with one exception.[1] Table 5-3 also shows that, with the exception of 1982, bus and trackless-trolley average fare has remained stable as well.

The decrease in the average fare between 1981 and 1982 cannot be explained for surface transit, as it can be for rapid transit, by a change in the fare structure. The free off-peak elderly fare, instituted in late 1981, affected a small proportion of total riders. It may have resulted in a slight reduction in the average fare, but not a reduction of the magnitude indicated by the survey results. Similarly, the increase in the average fare between 1982 and 1983 cannot be explained by the replacement of the off-peak elderly fare with a ten-cent fare in effect at all times. It is difficult to determine the actual reasons for the low estimated average fare in 1982.

To produce a composite estimate of the surface-transit fare mix and average fare, weights in accordance with the percentage of total surface ridership were applied to the surface-Green Line, trackless-trolley, and bus fare mixes. The results are presented in Table 5-4. The 1984 fare mix results support those of 1982, with the exception of the elderly-and-handicapped and adult-cash categories. This is not surprising in light of the fact that an oversampling of the 1982 elderly fare category had previously been suspected when it was compared to the 1978 bus survey results. The 1984 average fare is in line with that of 1981 and 1983 and further indicates difficulty with the 1982 average fare mentioned above. The 1982 average fare of 36.7¢ is

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[1]The Lynn garage shows a dramatic increase in average fare from 1983 to 1984 despite adjustment for an oversampling of express-bus routes. It is possible that the increase is the result of a ridership diversion from commuter rail to buses caused by a fire that put the bridge at North Station out of service from February 1984 to April 1985.

	CABOT[1]				ARBORWAY				SALEM[2]				SOMERVILLE[3]			
	1981	1982	1983	1984	1981	1982	1983	1984	1981	1982	1983	1984	1981	1982	1983	1984
Adult Cash	37.9%	32.9%	40.2%	33.6%	31.8%	33.3%	30.9%	38.1%	38.9%	37.6%	38.1%	33.0%	45.1%	37.6%	35.4%	37.2%
Prepaid Pass	34.5	40.9	37.8	34.3	28.4	34.3	36.8	43.0	21.7	32.1	31.0	40.5	40.9	34.9	32.7	37.8
E&H Half Fare	3.4	3.5	-	-	7.0	2.5	-	-	5.9	8.1	-	-	4.2	3.3	-	-
E&H Free	6.3	11.1	-	-	7.6	13.8	-	-	10.6	6.2	-	-	3.6	12.8	-	-
E&H Reduced Fare	-	-	8.2	11.0	-	-	12.3	11.4	-	-	10.5	15.2	-	-	15.3	12.0
Student and Children Half-Fare	10.3	7.5	7.8	11.9	17.0	10.6	11.9	3.1	21.3	11.4	18.3	8.2	4.8	9.2	15.2	10.5
Student Pass	6.1	3.2	5.2	7.7	6.0	5.2	7.6	3.7	0.8	4.5	1.6	2.1	0.6	1.5	1.1	1.8
Authorized Free	0.5	0.9	0.8	1.4	1.0	0.3	0.5	0.6	0.5	0.1	0.5	0.9	0.6	0.7	0.2	0.7
Unauthorized Free	0.7	0.0	0.0	0.1	1.2	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.2	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Average Fare[4]	41.0¢	38.2¢	44.3¢	37.5¢	35.0¢	32.6¢	37.7¢	39.2¢	39.4¢	37.2¢	35.1¢	39.4¢	42.7¢	36.0¢	36.7¢	37.7¢
Actual Confidence Interval	NA	±.9¢	±1.5¢	±1.4¢	NA	±1.2¢	±1.7¢	±1.1¢	NA	±1.4¢	±1.6¢	±1.8¢	NA	±1.2¢	±1.6¢	±1.5¢

[1]Includes Albany Garage [2]Includes Fellsway Garage [3]Includes Charlestown [4]Does not reflect pass revenue

1984 MBTA Fare-Mix Sampling Program

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BUS AND TRACKLESS-TROLLEY FARE MIX AND AVERAGE FARE BY GARAGE, 1981-1984 (WEEKDAY)

CTPS

TABLE 5-2(a)

	LYNN				QUINCY				BENNETT			
	1981	1982	1983	1984	1981	1982	1983	1984	1981	1982	1983	1984
Adult Cash	29.3%	40.1%	37.9%	33.0%	42.3%	36.0%	33.4%	40.9%	43.5%	31.3%	37.9%	38.1%
Prepaid Pass	28.7	18.6	27.7	29.8	20.1	21.7	21.8	20.2	44.2	45.1	36.5	36.9
E&H Half Fare	3.7	4.5	-	-	8.9	3.9	-	-	5.5	0.7	-	-
E&H Free	13.6	19.2	-	-	11.2	10.7	-	-	4.6	12.5	-	-
E&H Reduced Fare	-	-	12.7	12.2	-	-	21.0	15.2	-	-	10.5	17.0
Student and Children Half-Fare	24.4	9.7	10.6	13.4	16.7	14.8	22.4	20.5	2.0	5.4	10.2	6.3
Student Pass	0.4	4.3	10.6	10.3	0.0	11.3	1.1	3.2	0.8	5.0	3.4	0.7
Authorized Free	0.0	3.5	0.5	1.3	0.9	1.6	0.2	0.0	0.2	0.0	1.5	0.0
Unauthorized Free	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Average Fare	42.9¢	37.1¢	48.9¢	56.7¢	39.1¢	34.0¢	32.9¢	37.4¢	42.1¢	35.4¢	37.6¢	35.9¢
Actual Confidence Interval	NA	±1.8¢	±2.2¢	±3.1¢	NA	±2.0¢	±2.2¢	±2.8¢	NA	±1.5¢	±1.7¢	±1.8¢

1984 MBTA Fare-Mix Sampling Program

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BUS AND TRACKLESS-TROLLEY FARE MIX AND AVERAGE FARE BY GARAGE, 1981-1984
(WEEKDAY)

CTPS

TABLE 5-2(b)

		1981	1982	1983	1984
Fare					
Adult	- Cash	39.1%	35.1%	36.7%	36.1%
	- Pass	33.3	34.7	33.2	35.9
Elderly & Handicapped	- 1/2 Fare	5.2	3.8	-	-
	- Free	7.2	11.9	-	-
	- Reduced	-	-	11.9	13.0
Students & Children	- 1/2 Fare	11.4	9.3	13.0	9.7
	- Pass	2.9	4.2	4.5	4.3
Free	- Authorized	0.5	0.9	0.5	.9
	- Unauthorized	0.4	0.0	0.0	0.1
		100.0%	100.0%	100.0%	100.0%
Average Fare[1]		40.3¢	36.3¢	39.7¢	40.1¢
Confidence Interval of Average Fare					
		N.A.	±.6¢	±.7¢	±.9¢

[1]Does not reflect pass revenue.

1984 MBTA Fare-Mix Sampling Program	BUS AND TRACKLESS-TROLLEY FARE MIX 1981-1984 (WEEKDAY)	CTPS TABLE 5-3
Technical Report 55 June 1986		

		1981	1982	1983	1984
Fare Mix					
Adult	- Cash	36.9%	34.9%	36.4%	36.6%
	- Pass	30.7	32.6	31.4	33.2
Elderly & Handicapped	- Free	6.3	8.9	-	-
	- 1/2 Fare	5.3	4.3	-	-
	- Reduced	-	-	11.0	11.1
Student & Children	- 1/2 Fare	9.9	7.4	9.3	7.4
	- Pass	2.3	2.9	3.1	2.7
Free	- Authorized[1]	5.4	9.0	8.7	9.0
	- Unauthorized	0.5	-	-	-
		100.0%	100.0%	100.0%	100.0%
Average Fare[2]		41.1¢	36.7¢	39.1¢	40.9

[1]Includes passengers riding free in the outbound direction on the surface Green Line.

[2]Does not include pass revenue.

1984 MBTA Fare-Mix Sampling Program	WEIGHTED SURFACE-TRANSIT FARE MIX 1981-1984 (WEEKDAY & WEEKEND)	CTPS TABLE 5-4
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considerably lower than the 41.1¢ of 1981, the 39.1¢ of 1983, and the 40.9¢ of 1984.

In Table 5-5, the number of estimated trips, the average fare, and other summary data are presented for surface transit in 1981, 1982, 1983, and 1984. The table shows a consistent increase in pass trips, cash trips (with the exception of 1982), revenue, and pass sales over each of the survey periods. Surface-transit average fare is relatively consistent as well.

5.1.2 Rapid Transit

As mentioned previously, no rapid-transit survey was conducted in 1984. Instead, the 1983 fare mix is assumed to be the same for 1984 and the 1983 rapid-transit average fare of 51¢ has been applied to 1984 revenue data in order to estimate 1984 unlinked trips. The estimated rapid-transit fare mix, average fare, and number of unlinked trips for 1981 through 1984 are presented in Table 5-6.

Table 5-6 shows a 9.6-percent increase in the total number of unlinked trips (from 347,514 in 1983 to 380,779 in 1984). It is difficult to account for such a dramatic increase in ridership, and without 1984 survey data it is not possible to be reasonably certain that an increase of that magnitude did, in fact, occur. However, given the rapid-transit revenue increase from $3,797,495 in 1983 to $4,128,348 in 1984, one can be certain that there was at least some increase in ridership.

See the notes in Appendix 1 of this report for data-analysis procedures for 1984, and CTPS Technical Report 48 for analysis procedures from 1981-1983.

5.2 LINKED TRIPS

5.2.1 Data-Analysis Procedures

In order to link rapid-transit and surface trips, an estimate of the proportion of rapid-transit-only, surface-only, and combination (rapid transit and surface) trips is needed. For this year's analysis, as for 1983 and 1982, the source used was the 1978 System-wide Survey, which included a question about transfer behavior. Because of service cuts, fare increases, and transit-line extensions that took place after that survey was taken, 1981 proportions were changed slightly to 31-percent rapid-transit-only, 30-percent surface-only, and 39-percent combination. By November 1982, however, much of the cut service had been restored, and rapid-transit and pass fares had been reduced. Therefore, the 1978 proportions of 29 percent, 31 percent, and 40 percent, respectively, were thought to be more appropriate.

The actual process for linking trips for 1982 was not the same as that used in 1981, because it was thought that the

	1981	1982[1]	1983	1984
Unlinked Average Weekday Trips				
Pass	139,301	147,410	152,652	164,139
Cash	282,824	279,866	289,818	293,074
Total	422,125	427,276	442,470	457,213
Survey-Period Revenue	$3,656,678	$3,451,370	$3,614,588	$3,797,712
Average Fare	39.6¢	37.1¢	37.6¢	38.2¢
Pass Sales (Nov.)	58,184	62,697	70,164	71,915
Uses per Pass/ Period	53	51	48	51

[1]Revised

1984 MBTA Fare-Mix Sampling Program Technical Report 55 June 1986	SURFACE-TRANSIT SUMMARY 1981-1984	CTPS TABLE 5-5

		1981	1982	1983	1984[1]
Fare Mix					
Adult	- Cash	48.5%	49.9%	48.6%	-
	- Pass	29.2	32.3	32.3	-
Elderly & Handicapped	- Free	11.1	8.9	NA	-
	- 1/2 Fare	3.8	3.2	NA	-
	- Reduced	NA	NA	13.5	-
Students & Children	- 1/2 Fare	5.8	1.9	1.6	-
	- Pass	NA	2.9	3.3	-
Free	- Authorized	1.2	0.8	0.5	-
	- Unauthorized	0.4	0.2	0.2	-
		100.0%	100.0%	100.0%	
Average Fare		60.0¢	50.4¢	51.0¢	-
Total Unlinked Trips (Average Weekday)[2]		305,000	335,581	347,514	380,779[3]

NA = not applicable

[1]Rapid-transit fare mix was not sampled in 1984

[2]Includes pass trips

[3]1983 average fare of 51¢ applied to 1984 revenue data

1984 MBTA Fare-Mix Sampling Program	RAPID-TRANSIT FARE MIX 1981-1984 (WEEKDAY)	CTPS TABLE 5-6
Technical Report 55 June 1986		

accuracy of the 1981 process could be improved by assuming that the proportion of combination trips is more accurate than the individual surface-only and rapid-transit-only proportions. Simultaneous equations were used to find the total number of combination trips, which was then subtracted from total unlinked rapid-transit trips and total unlinked surface trips to find rapid-transit-only and surface-only trips.

This method has remained in effect for 1983 and 1984. The 1981 trips were re-linked using the new method so that the results would be compatible with those of subsequent years.

5.2.2 Results

Table 5-7 provides a summary of average-fare and ridership calculations from 1981 through 1984. The average fare decreased from 71.1¢ in 1981 to 63.5¢ in 1982, while there was an increase of 4.6 percent in the number of average-weekday linked trips (from 490,900 in 1981 to 513,500 in 1982). In 1983 the number of linked trips was 531,760, an increase of 3.6 percent over 1982, and the average system-wide fare was 64.1¢. For 1984, linked trips of 565,898 represented an increase of 6.4 percent over 1983. The average fare was 64.4¢. It should be noted that, because the rapid-transit survey was not conducted in 1984, estimated rapid-transit unlinked trips have been calculated by applying the 1983 average fare to 1984 revenue data. Results obtained from this method of estimation obviously have an impact on linked trips as well. Therefore, the same considerations that were previously discussed regarding the apparent rapid-transit ridership increase should also be noted regarding the apparent system-wide ridership increase. In addition, it should be noted that some changes in revenue-collection practices (to insure against losses) in May of 1984 may affect comparisons of revenue/ridership figures before and after that date.

The calculations for 1984 linked trips are summarized in Appendix 1, Part 3.

	Rapid Transit				Surface Transit			
	1981	1982	1983	1984[2]	1981	1982	1983	1984
Unlinked Average Weekday Trips								
Token	141,759	155,255	157,143	-				
Pass - Passmeter	(77,044)	(87,647)	(90,116)	-				
- Passholders using gates or collector's turnstiles	(13,301)	(22,581)	(29,876)	-				
Subtotal	90,345	110,228	119,992	-	139,301	147,410	152,652	164,139
Cash	73,595	70,128	70,379	-	282,824	279,866	289,818	293,074
Total	305,699	335,581	347,514	380,779[3]	422,125	427,276	442,470	457,213
Survey-Period Revenue	$3,932,827	$3,636,496	$3,797,495	$4,128,347	$3,656,678	$3,451,370	$3,614,588	$3,797,712
Average Fare	60.0¢	50.4¢	51.0¢	-	39.6¢	37.1¢	37.6¢	38.2¢
Pass Sales (Nov.)[1]	50,432	60,053	64,894	70,147	58,184	62,697	70,164	71,915
Uses per Pass/Period	38	39	37	-	53	61	48	51

	1981	1982	1983	1984
Linked Trips per Average Weekday	490,900	513,500	531,760	565,898
Average Fare	71.1¢	63.5¢	64.1¢	64.6¢

[1]Pass sales for the month of November are given to provide a consistent base for uses per pass/period.
[2]A rapid-transit survey was not conducted in 1984.
[3]Estimate calculated by applying 1983 average fare to 1984 revenue.

1984 MBTA Fare-Mix Sampling Program
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SUMMARY OF 1981-1984 AVERAGE-FARE AND RIDERSHIP CALCULATIONS

CTPS
TABLE
5-7

6 STATISTICAL ANALYSIS

The estimated average fare mix can be used to estimate boardings within a confidence interval of ±2.5 percent.

The actual confidence intervals at a 95-percent confidence level and sample sizes for the bus system, the Green Line, and collector's turnstiles are presented on the following pages. Except for fare mixes by bus garage, the confidence intervals are less than ±2.5 percent.

	Weekday	Weekend
Adult Cash	±0.92%	±1.46%
Adult Pass	±0.92%	±1.36%
E&H Reduced Fare	±0.64%	±1.11%
Student & Children 1/2 Fare	±0.57%	±0.68%
Student Pass	±0.39%	±0.16%
Authorized Free	±0.18%	±0.37%
Unauthorized Free	±0.06%	-

*95% confidence level

1984 MBTA Fare-Mix Sampling Program Technical Report 55 June 1986	ACTUAL CONFIDENCE INTERVALS* BUS	CTPS TABLE 6-1

	Arborway	Cabot	Salem	Somerville	Lynn	Quincy	Bennett
Adult Cash	±2.08%	±2.05%	±2.44%	±2.35%	±2.71%	±3.08%	±2.90%
Adult Pass	±2.09%	±2.09%	±2.54%	±2.36%	±2.63%	±2.64%	±2.88%
E&H Reduced Fare	±1.38%	±1.34%	±1.86%	±1.58%	±1.88%	±2.52%	±2.24%
Student and Children 1/2 Fare	±1.43%	±1.73%	±1.42%	±1.49%	±1.96%	±2.25%	±1.45%
Student Pass	±1.17%	±0.80%	±0.74%	±0.65%	±1.75%	±2.53%	±0.50%
Authorized Free	±0.50%	±0.32%	±0.49%	±0.41%	±0.65%	-	±0.59%
Unauthorized Free	-	±0.13%	±0.16%	-	-	-	-

*95% confidence level

1984 MBTA Fare-Mix Sampling Program Technical Report 55 June 1986	ACTUAL CONFIDENCE INTERVALS* BY BUS GARAGE (WEEKDAY)	CTPS TABLE 6-2

	Arborway	Cabot	Salem	Somerville	Lynn	Quincy	Bennett	TOTAL
Adult Cash	664	823	472	603	382	400	411	3,755
Adult Pass	677	928	580	613	345	197	399	3,739
E&H Reduced Fare	218	246	218	194	142	149	183	1,350
Student and Children 1/2 Fare	235	66	117	171	156	200	68	1,013
Student Pass	151	80	30	29	119	31	8	448
Authorized Free	27	13	13	12	15	0	11	91
Unauthorized Free	2	2	2	0	0	0	0	6
TOTAL	1,974	2,158	1,432	1,622	1,159	977	1,080	10,402

1984 MBTA Fare-Mix Sampling Program
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NUMBER COUNTED BY BUS GARAGE AND FARE TYPE

CTPS
TABLE
6-3

	Weekday		Weekend	
	Number Counted	Confidence Interval	Number Counted	Confidence Interval
Adult Cash	1,891	±1.19%	2,128	±1.34%
Adult Pass	1,640	±1.14%	1,310	±1.19%
E&H Reduced Fare	240	±0.51%	277	±0.62%
Student and Children 1/2 Fare	71	±0.28%	97	±0.37%
Student Pass	47	±0.23%	-	-
Authorized Free	2,030	±1.21%	1,341	±1.20%
Unauthorized Free	1	-	11	±0.12%
TOTAL	5,920		5,164	

*95% confidence level

1984 MBTA Fare-Mix Sampling Program	ACTUAL CONFIDENCE INTERVALS* SURFACE GREEN LINE	CTPS
Technical Report 55 June 1986		TABLE 6-4

7 SUMMARY AND RECOMMENDATIONS

7.1 SUMMARY

The purpose of the annual fare-mix survey is to provide current data on the type of fare paid by a sample of transit riders. From this information is derived an average fare, which, combined with revenue data, is used to estimate current ridership.

For the purpose of the survey, the MBTA system is divided into three sections: surface transit, rapid transit, and the surface portions of the Green Line. MBTA checkers surveyed trips from each component to provide separate estimates of average fare and unlinked ridership. These figures are combined to produce an estimate of linked trips and an estimated average fare.

The results of the analyses show that both linked and unlinked trips have increased from 1981 through 1984 and that, with the exception of 1981, when the basic adult rapid-transit fare was considerably higher than in other years, both linked and unlinked average fares have increased very gradually as well.

The cost of conducting the count is estimated to have been approximately $31,000; the preparation, processing, and analysis of data also cost approximately $31,000.

7.2 RECOMMENDATIONS

The following points should be taken into consideration in planning and implementing all future surveys.

- The bias in the 1982 survey toward the elderly-and-handicapped fare category may be the result of a large proportion of the survey taking place during off-peak times, when the free elderly fare was in effect (it has not been ascertained whether this proportion of the surveying was in fact large). If another time-related fare category is instituted in the future, this type of bias may again be an issue. To avoid the problem, the time of day should be controlled in the survey.

- The reduced sample size that was instituted in 1983 continues to provide an acceptable level of validity for surface transit. However, if in the next survey the fare mix is still required by district, care should be taken not to oversample zoned and express bus runs, particularly those in the smaller districts. In addition, it is important to continue to sample both surface

and rapid-transit service so that reasons for apparent variations can be more readily established.

- Some thought should be given to doing the bus survey on a system-wide basis rather than district by district. System-wide data have been far more consistent and they could be collected and processed faster and at a lower cost.

- A rapid-transit survey should be conducted every year rather than every other year, so that the causes of year-to-year variations in revenue can be accurately assessed.

APPENDIX 1

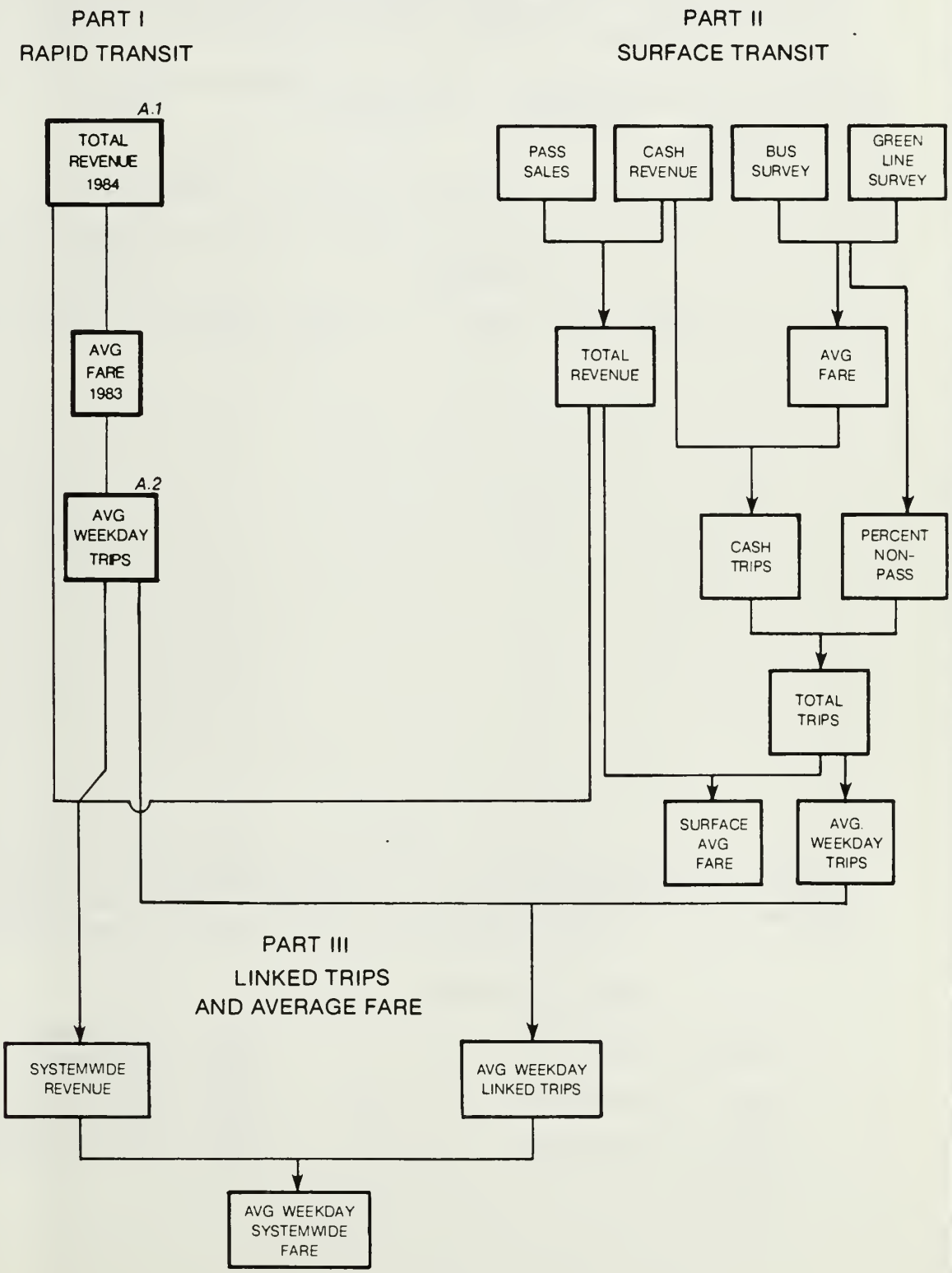
Annotated* Flow Diagram
of
1984 Fare-Mix and Ridership Estimation

		Page
Overview		39
Part I:	Rapid Transit (notes re Overview diagram)	41
Part II:	Surface Transit	43
Part III:	Linked Trips and Average Fare	57

*Notes, which follow each part of the diagram, are referred to by the designations at the upper right-hand corner of diagram boxes.

FLOW DIAGRAM OF 1984 FARE-MIX AND RIDERSHIP ESTIMATION

OVERVIEW



NOTES

Part I - Rapid Transit (Unlinked Trips)

In the absence of 1984 rapid-transit survey data, 1984 average weekday rapid-transit unlinked trips were estimated according to the formula below. See CTPS Technical Report 48, Appendix 1, Part 1 for 1983 rapid-transit fare-mix and average-fare results.

$$\left(\begin{matrix}\text{1984 Period 5} \\ \text{revenue}\end{matrix} \div \begin{matrix}\text{1983 Average} \\ \text{fare}\end{matrix}\right)\left(\begin{matrix}\text{\% Weekday} \\ \text{trips}\end{matrix} \div \begin{matrix}\text{Weekday} \\ \text{factor}[1]\end{matrix}\right) = \begin{matrix}\text{1984 Unlinked} \\ \text{rapid-transit} \\ \text{trips}\end{matrix}$$

$(4{,}128{,}347 \div 51.0¢)(.882 \div 18.75) = 380{,}779$

A.1 Average weekday unlinked rapid-transit trips Period 5, 1984 = 380,779

A.2 Rapid-transit revenue, Period 5, 1984 = $4,128,397

---

[1]21.75 represents the number of weekday-equivalent days in Period 5, 1984 (October 27-November 23). It is calculated from factors which reflect the type of schedule (as a percentage of a weekday schedule) that is in effect on a particular date.

Weekday = 1.00
Saturday = 0.50
Sunday = 0.25
Thanksgiving Day = 0.25
Veteran's Day = 0.50

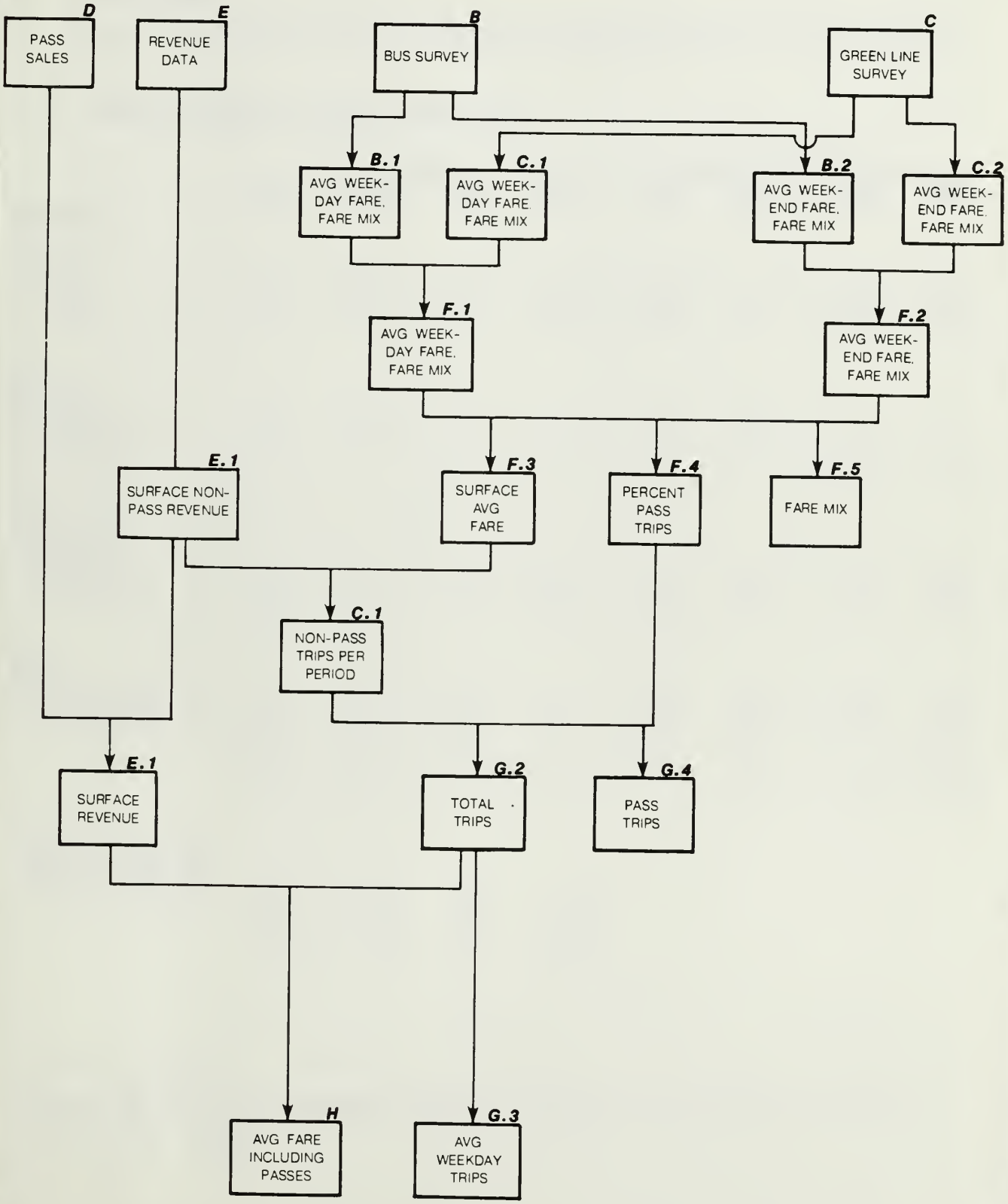
Period 5, 1984:

Weekdays =	18.00
4 Weekends =	3.00
Holidays =	0.75
	21.75

FLOW DIAGRAM OF 1984 FARE-MIX AND RIDERSHIP ESTIMATION

PART II

SURFACE TRANSIT



NOTES

Part II - Surface Transit (Unlinked Trips)

B. BUS SURVEY

The survey conducted on the bus lines produced the following results:

B.1 Average Weekday Fare, Fare Mix

	Bus				Trackless Trolley			
Fare Mix	1981	1982	1983	1984	1981	1982	1983	1984
Adult								
- Cash	38.6%	35.4%	36.7%	35.9%	43.1%	31.3%	37.9%	38.1%
- Pass	32.1	33.9	33.1	35.9	43.0	45.1	36.5	36.9
E&H								
- Free	7.4	11.9	-	-	5.7	12.5	-	-
- 1/2 Fare	5.2	4.1	-	-	5.4	0.7	-	-
- Reduced	-	-	12.0	12.5	-	-	10.5	16.9
Students & Children								
- Pass	3.2	4.1	4.5	4.7	-	5.0	3.4	0.7
- 1/2 Fare	12.4	9.6	13.1	10.1	2.4	5.4	10.2	6.3
Free								
- Authorized	0.6	1.0	0.5	0.8	0.4	0.0	1.5	1.0
- Unauthorized	0.5	0.0	0.0	0.1	0.0	0.0	0.0	0.0
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Average fare[1] for bus & trackless trolley combined	1981	1982	1983	1984
	40.3¢	36.3¢	39.7¢	40.1¢

[1]The average fare represents the weighted average by bus garage and does not include pass revenue.

B.2 Average Weekend Fare, Fare Mix, for Bus[1]

Fare Mix	1981	1982	1983	1984
Adult				
- Cash	46.5%	39.6%	46.4%	44.2%
- Pass	28.4	37.0	30.4	31.0
E&H				
- Free	0.8	-	-	-
- 1/2 Fare	11.7	14.6	-	-
- Reduced	-	-	15.2	17.3
Students & Children				
- Pass	0.3	-	-	-
- 1/2 Fare	9.2	7.1	5.7	5.6
Free				
- Authorized	2.2	1.5	2.1	1.6
- Unauthorized	0.9	0.2	0.2	0.3
	100.0%	100.0%	100.0%	100.0%
Average fare	41.5¢	41.9¢	39.0¢	43.2

[1]Trackless trolleys do not operate on weekends.

C. GREEN LINE SURVEY

The survey conducted on the surface portion of the Green Line resulted in the following fare mix and average fare.

	C.1 Weekday				C.2 Weekend			
Fare Mix	1981	1982	1983	1984	1981	1982	1983	1984
Adult								
-Cash	38.4%	29.6%	31.1%	31.9%	44.3%	41.6%	35.6%	41.2%
-Pass	25.3	27.4	28.0	27.7	22.9	21.1	23.0	25.4
E&H								
-Free	5.9	3.6	-	-	0.4	-	-	-
-1/2 Fare	1.6	0.9	-	-	4.4	4.4	-	-
-Reduced	-	-	7.3	4.1	-	-	5.8	5.3
Students & Children								
-Pass	0.2	0.1	0.8	0.8	-	-	-	-
-1/2 Fare	1.1	1.5	1.5	1.2	1.8	1.3	1.3	1.9
Free								
-Authorized	27.0	36.9	31.2	34.3	26.2	31.4	34.3	26.0
-Unauthorized	0.0	-	0.1	0.0	-	0.2	0.1	0.2
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Average fare[1]	41.7¢	33.7¢	37.4¢	40.6¢	48.2¢	45.7¢	40.4¢	49.0¢

[1]The average fare represents the weighted average of the four components of the surface Green Line and does not include pass revenue.

D. PREPAID-PASS SALES

The following table presents lists pass sales for the month of November and the proportion used on the surface system. See the next page for notes on pass types.

Distribution of Passes

Type of Pass[1]	Total Passes		Proportion Used on Surface	
	No.	Revenue	No.	Revenue
A $18	18,196	$ 327,528	18,196 (100.0%)	$ 327,528
B $22	39,503	869,066	5,333 (13.5%)	117,324 (13.5%)
C $36	29,074	1,046,664	27,765 (91.0%)	476,232 (41.0%)
D $40	4,403	176,120	3,258 (74.0%)	93,344 (53.0%)
E $48	4,936	236,928	4,936 (100.0%)	154,003 (65.0%)
F $56	1,232	68,992	1,232 (100.0%)	34,496 (50.0%)
	97,344	$2,725,928	60,720	$1,202,927

	Number	Revenue
Commutation tickets (express bus & Green Line only)	2,366	$33,124
Student passes (surface transit)	11,195	$91,685

Note to table, "Distribution of Passes," on preceding page:

[1]The table shows the cost of each pass; the maximum value per trip and the mode(s) are as follows:

A - $0.50 Surface vehicle only

B - $0.60 Rapid transit (including Mattapan High-speed Line) and streetcar

C - $1.00 Rapid transit, streetcar, bus, and express bus

D - $1.25 Rapid transit, streetcar, bus, express bus, and zone 1 commuter rail

E - $1.50 Rapid transit, streetcar, bus, express bus, and zone 2 commuter rail

F - $1.75 All MBTA services and zone 3 commuter rail

Passes are purchased on a calendar-month basis, so revenue and number of passes must be converted to equivalent period figures. The conversion method is the same as the one that was used for 1983. That is, the portion of October days contained in period 5 of fiscal year 1984 was applied to sales for that month and the portion of November days not included in period 5 was applied to November sales. November sales were adjusted by these figures to arrive at period-5 values. Student passes and revenue were simply discounted by 8 percent, because they did not vary significantly between the two months. The 8-percent discount represented the ratio between the number of days in November and in period 5 of fiscal year 1984.

October weekday equivalent[1]	=	25.25
November weekday equivalent	=	23.75
Portion of October in Period 5		
October 27-31 = 3.75 days		
3.75 ÷ 25.25	=	14.9%
Portion of November not in Period 5		
November 23-30 = 5.75 days		
5.75 ÷ 23.75	=	24.2%

---

[1]For explanation of weekday-equivalent days, see footnote on page 41.

Surface Transit

Revenue

October revenue adjustment
1,139,117 x .149 = 169,728

November revenue adjustment
1,202,927 x .242 = 291,108

Period-5 pass revenue
1,202,927 - 291,108 + 169,728 = $1,081,547

Number of Passes

October proportion 3.75 ÷ 21.75 = .172
November proportion 18 ÷ 21.75 = .828

Period-5 passes
(60,720 x .828) + (57,475 x .172) = 60,162

Student passes
11,195 ÷ 1.08 = 10,366

Total Period-5 passes = 70,528

E. REVENUE

The revenue for Period 5, 1984, distributed to surface transit and the revenue for Period 5, 1983 distributed to rapid transit are as follows:

E.1 Surface Revenue, Period 5, 1984

Farebox revenue		$2,631,271/period
Non-farebox revenue		
Prepaid pass	$1,202,927/November $1,139,117/October	1,081,547/period[1]
Student pass	$91,685/month	84,894/period
Total surface revenue		$3,797,712/period

E.2 Rapid-Transit Revenue, Period 5, 1984

Total rapid-transit revenue	$4,128,347/period

E.3 Total Revenue $7,926,059

---

[1]For the adjustment of monthly pass revenue to an accounting-period basis, see page 49.

F. AVERAGE FARE AND FARE MIX (SURFACE TRANSIT)

Ridership estimates are derived for the bus and trackless trolley systems and surface Green Line using average fares and Period 5 revenue. These ridership figures are then used in weighting the average fare and fare-mix to arrive at composite estimates. The calculations for average fare and adult pass use are given below.

Weekday	Revenue	÷	Avg. Fare	=	Ridership Estimate	Proportion of Total Ridership
Bus	$88,276	÷	$.403	=	219,047	.734
Trackless Trolley	$ 3,369	÷	$.359	=	9,384	.031
Green Line	$28,473	÷	$.406	=	70,131	.235
Weekend						
Bus	$78,382	÷	$.432	=	181,440	.664
Green Line	$44,893	÷	$.490	=	91,618	.336

F.1 Average Weekday Fare and Percentage Pass Use

Average Fare Ridership Proportion for Bus, Trackless Trolley and Green Line: ($.403)(.734) + ($.359)(.031) + (.406)(.235) = 40.2¢

Proportion of Pass use for Bus, Trackless Trolley and Green Line:
(.359)(.734) + (.369)(.031) + (.277)(.235) = 34.0%

F.2 Average Weekend Fare and Percentage Pass Use

Average Fare ($.432)(.664) + ($.490)(.336) = 45.1¢
Pass (.31)(.664) + (.254)(.336) = 29.1%

Combining the weekday and weekend averages yields a composite average fare (J.3), pass use (J.4) and fare mix (J.5).

F.3 Average Fare

($.402)(.829) + ($.451)(.171) = 40.9¢

F.4 Percent Pass

(.340)(.829) + (.291)(.171) = 33.2%

Weighted average of student pass use = 2.7%

Total = 35.9%

F.5 Fare Mix

	Weekday and Weekend			
	1981	1982	1983	1984
Adult				
- Cash	39.6%	34.9%	36.4%	36.6%
- Pass	30.7	32.6	31.4	33.2
E&H				
- Free	6.3	8.9	-	-
- 1/2 Fare	5.3	4.3	-	-
- Reduced	-	-	11.0	11.1
Students & Children				
- Pass	2.3	2.9	3.1	2.7
- 1/2 Fare	9.9	7.4	9.3	7.4
Free				
- Authorized[1]	5.4	9.0	8.7	9.0
- Unauthorized	0.5	-	-	-
	100.0%	100.0%	100.0%	100.0%
Average Fare[2]	41.1¢	36.7¢	39.1¢	40.9¢

[1]Includes passengers riding free in the outbound direction on the surface Green Line.

[2]Does not include pass revenue.

G. SURFACE TRIPS

The number of unlinked average weekday surface trips was estimated using the composite average fare and surface revenue for Period 5.

Surface non-pass revenue (E.1)
less commutation-ticket revenue (D)

2,631,271 - 33,124 = 2,598,147

G.1 Non-pass Trips per Period

Revenue ÷ Non-pass avg. fare = 2,598,147 - .409 = 6,352,438

Plus ticket trips

23,666 ÷ 1.08 = 21,913 per period
6,352,438 + 21,913 = 6,374,351

G.2 Total Trips per Period

Non-pass trips ÷ Fraction of total that are non-pass

6,374,351 ÷ .641 = 9,944,385

G.3 Average Weekday Trips

Total trips ÷ Factored avg. weekdays

9,944,385 ÷ 21.75 = 457,213

G.4 Uses per Prepaid Pass

Pass trips ÷ Passes used on surface per period

(9,944,385 - 6,374,351) ÷ 70,528 = 50.6 uses per period

50.6 ÷ 21.75 = 2.3 uses per day

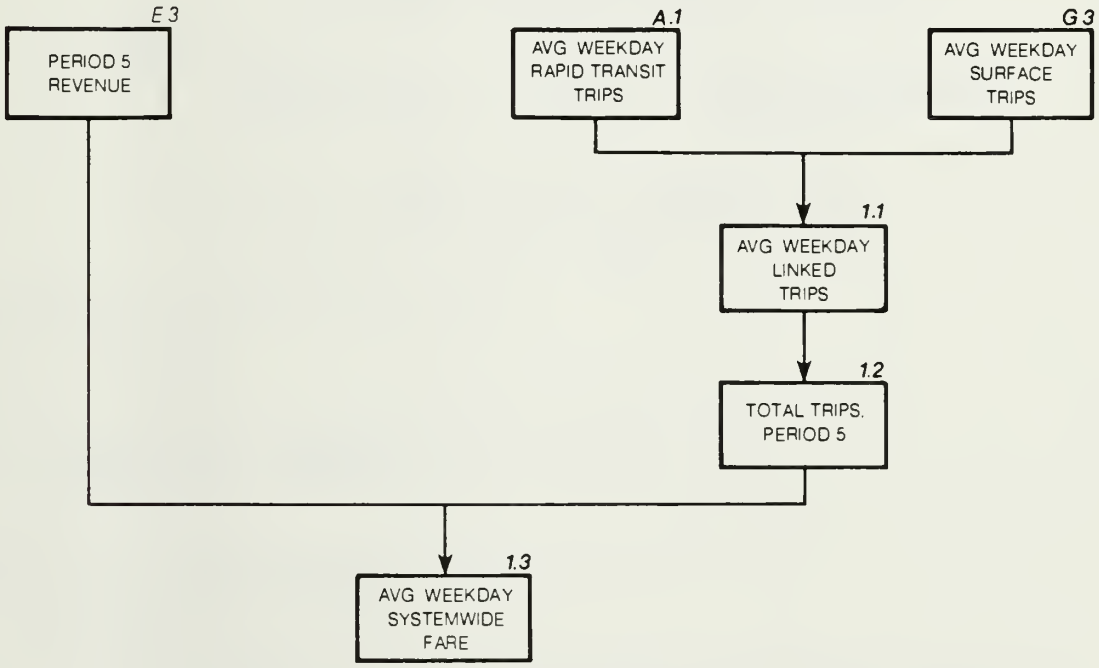
H. AVERAGE FARE FOR UNLINKED SURFACE TRIPS

Total surface revenue (E.1)	÷	Total surface trips (G.2)	
3,797,712	÷	9,944,385	= 38.2¢

FLOW DIAGRAM OF 1984 FARE-MIX AND RIDERSHIP ESTIMATION

PART III

LINKED TRIPS AND AVERAGE FARE



NOTES

Part III - Linked Trips and Average Fare

I. Average weekday linked trips and the corresponding average fare were estimated using the following procedure:

Unlinked rapid-transit trips = 380,779
Unlinked surface trips = 457,213

Rapid transit only = X (29%)
Combination = Y (40%)
Surface only = Z (31%)
(Percentages from 1978 System-wide Survey)

$X + Y = 380,779$ $(X = 347,514 - Y)$
$Z + Y = 457,213$ $(Z = 457,213 - Y)$
$Y \div (X + Y + Z) = .40$

Solving the third equation:

$Y = 239,426$

X = (unlinked rapid-transit trips) - Y
= 380,779 - 229,922
= 141,353

Z = (unlinked surface trips) - Y
= 457,213 - 239,426
= 217,787
15% of these trips are surface-to-surface transfers
= 217,787 x .85
= 185,119

I.1 X + Y + Z = total linked trips/weekday
141,353 + 185,119 + 239,426 = 565,898

I.2 Weekday linked trips x period factor = linked trips/period
565,898 x 21.75 = 12,308,281

I.3 Average fare
$7,926,059 ÷ 12,308,281 = 64.4¢

Total unlinked trips per period
457,213 + 380,779 = 837,992
(G.3) (A.1)

APPENDIX 2

Survey Samples and Schedules

TABLE A-2a

RUNS SAMPLED PER GARAGE
1984

Garage	Total Weekday Runs	Runs Sampled
Cabot	214	3
Arborway	140	5
Salem	198	6
Somerville	138	5
Lynn	107	5
Quincy	88	4
Bennett[1]	32	4
	917	32

Garage	Total Weekend Runs	Runs Sampled
Cabot	136	3
Arborway	108	3
Salem	142	3
Somerville	122	3
Lynn	84	3
Quincy	72	3
	664	18

[1]Trackless trolley

TABLE A-2b

SURFACE-GREEN-LINE SURVEY SCHEDULE
1984

Branch	Valid Trips	Trips Required	Date(s)
Weekday			
Boston College	24	10	1/16/85
Cleveland Circle	22	8	12/3-12/5/84
Riverside	26	9	12/3-12/5/84, 1/16/85
Arborway	24	7	12/3-12/5/84
Weekend			
Boston College	28	12	12/2/84, 12/8/84, 1/12/85
Cleveland Circle	26	9	12/2/84, 12/8/84
Riverside	28	11	12/2/84, 12/8/84
Arborway	26	9	12/2/84, 12/8/84

TABLE A-2c, p.1

BUS AND TRACKLESS-TROLLEY SURVEY SCHEDULE
1984

Day of Week	District	Run Number[1]	Date of Count
Weekday	Cabot	1015	11/20
		1502	12/14
		1548	11/20
	Arborway	1029	11/19
		1054	11/19
		1095	11/19
		1099	11/19
		9022	11/19
	Salem	146	11/28
		147	11/28
		1007	11/26
		1062	11/26
		1078	11/26
		9052	11/26
	Somerville	1039	11/27
		1046	12/14
		1061	11/27
		9008	11/27
		9017	11/27
	Lynn	1014	11/28
		1019	11/28
		1054	11/28
		9005	11/28
		9018	11/28
	Quincy	1010	11/30
		1021	11/30
		9023	11/30
		9026	11/30
	Bennett[2]	1505	11/26
		1520	12/10
		9055	11/26
		9057	11/26

[1]Any run that has a run number starting with a 9 is handled by a part-time driver.

[2]Trackless trolley

TABLE A-2c, p.2

BUS AND TRACKLESS-TROLLEY SURVEY SCHEDULE
1984

Day of Week	District	Run Number	Date of Count
Saturday	Cabot	2069	11/17
		2086	11/17
	Arborway	2018	11/17
		2034	11/17
	Salem	2057	12/1
		2095	12/1
	Somerville	2078	12/1
		2088	12/1
	Quincy	2023	11/17
		2030	11/17
	Lynn	2013	12/1
		2033	12/1
Sunday	Cabot	3007	11/18
	Arborway	3010	11/18
	Salem	3012	11/18
	Somerville	3027	11/18
	Quincy	3021	11/18
	Lynn	3018	11/18

APPENDIX 3

Average Weekday Pass Usage by Garage

TABLE A-3

AVERAGE WEEKDAY PASS USAGE
ON SURFACE TRANSIT BY GARAGE
1984

Arborway	15.6%
Cabot	16.9
Salem	11.3
Somerville	13.8
Lynn	9.1
Quincy	7.7
Bennett*	3.1
Green Line	23.5
	100.0%

*Trackless trolley

APPENDIX 4

Survey Forms

FARE MIX AND RIDERSHIP CHARACTERISTICS
GREEN LINE SURVEY FORM

NAME				DATE		1	2	3	4	5	
CAR HOUSE			6	VEHICLE #		7	8	9	10		
ROUTE #		11	12	13	DIRECTION	O INBOUND O OUTBOUND					14
START TIME	A.M. P.M.	15	16	17	18						

PASSENGER COUNTING

ADULT	CASH FARE		19	20	21
	PASS		22	23	24
E & H	REDUCED FARE		25	26	27
STUDENT & CHILDREN	1/2 FARE		28	29	30
	PASS		31	32	33
OTHER FREE	AUTHORIZED		34	35	36
	NON AUTHORIZED		37	38	39

PORTAL LOAD COUNT

# ONBOARD AFTER LAST ABOVE GROUND STOP INBOUND		40	41	42	# ONBOARD AFTER LAST BELOW GROUND STOP OUTBOUND		43	44	45

FARE BOX READING

CASH	BEGIN:	46	47	48	49	50	CASH	END:	51	52	53	54	55		
PENNY	BEGIN:	56	57	58	59	60	PENNY	END:	61	62	63	64	65		
TOKEN	BEGIN:	66	67	68	69	70	TOKEN	END:	71	72	73	74	75		
$ BILLS RECEIVED DURING TRIP														76	77	78

FARE MIX AND RIDERSHIP CHARACTERISTICS
BUS SURVEY FORM

NAME		DATE	1 2 3 4 5
GARAGE	6 7	BUS #	8 9 10 11
RUN #	12 13 14 15	ROUTE #	16 17 18
DIRECTION	O INBOUND O OUTBOUND 19	SCHEDULED START TIME	O AM O PM 20 21 22 23
ACTUAL START TIME	O AM O PM 24 25 26 27	ACTUAL ARRIV TIME	O AM O PM 28 29 30 31

PASSENGER COUNTING

ADULT	CASH FARE	32 33 34
	PASS	35 36 37
E & H	REDUCED FARE	38 39
STUDENT & CHILDREN	HALF FARE	40 41
	PASS	42 43
OTHER FREE	AUTHORIZED	44 45
	NON AUTHORIZED	46 47

FARE BOX READING

CASH	BEGIN:	48 49 50 51 52	CASH	END:	53 54 55 56 57
PENNY	BEGIN:	58 59 60 61 62	PENNY	END:	63 64 65 66 67
TOKEN	BEGIN:	68 69 70 71 72	TOKEN	END:	73 74 75 76 77
$ BILLS					78 79 80

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CTPS TECHNICAL REPORT

57

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1985 MBTA FARE-MIX SAMPLING PROGRAM: ANALYSIS AND DOCUMENTATION

January 1987

CTPS TECHNICAL REPORT 57

TITLE 1985 MBTA Fare-Mix Sampling Program: Analysis and Documentation

AUTHOR(S) Mary Ellen Sullivan
Alicia Powell Wilson

DATE January 1987

ABSTRACT This report describes the assumptions and methods used to design and administer a sampling program to determine the fare mix and average fare for rapid transit, buses, and the surface Green Line. The information obtained from this program was used in conjunction with revenue data to determine the number of unlinked and linked trips made on rapid-transit and surface routes on typical days in 1985.

This document was prepared by **CENTRAL TRANSPORTATION PLANNING STAFF**, an interagency transportation planning staff created and directed by the Metropolitan Planning Organization, consisting of the member agencies.

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Massachusetts Bay Transportation Authority
Massachusetts Department of Public Works
MBTA Advisory Board
Massachusetts Port Authority
Metropolitan Area Planning Council

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This document was prepared in cooperation with the Urban Mass Transportation Administration of the U. S. Department of Transportation through the technical study grant(s) cited below, and was also financed with state and local matching funds.

MA-08-0126
MA-08-0135

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ACKNOWLEDGMENTS

The sampling program used this year and previous years was designed and developed with the invaluable assistance of Alan Castaline and other MBTA personnel. The formidable task of data collection was performed by the MBTA traffic checkers.

1 OVERVIEW

Historically, the MBTA has estimated daily and annual ridership by dividing collected revenue by an average fare. In 1981 it was decided that, because of various fare and system changes, the average-fare figure being used was no longer valid. In addition, accurate data were needed to develop pricing and marketing policies and to satisfy federal reporting requirements.

Therefore, in November of 1981, the MBTA instituted a new program for estimating ridership whereby the average fare used to calculate the number of riders from revenue is determined by surveying a sample of actual ridership. The number of passengers boarding, the type of fare they paid, and farebox revenue are recorded for selected bus routes, on the surface portions of the Green Line, and at selected rapid-transit stations. The resulting data are processed and analyzed by the Central Transportation Planning Staff (CTPS).

This report presents the 1985 survey results and analysis procedures and the four previous years' results. The analyses, as well as the results, of the 1981-1984 fare-mix surveys are available in CTPS Technical Reports 39, 43, 48, and 55.

The estimated unlinked average-weekday rapid-transit and surface trips, as well as linked trips and the average fares for each category for each of the survey years, are presented in Table 1-1. Linked trips are trips composed of a combination of rapid-transit and surface trips. Trip-making patterns obtained from the 1978 systemwide survey indicate that 29 percent of all MBTA trips are rapid-transit-only, 31 percent are surface-only, and 40 percent are a combination of surface and rapid-transit trips.

	1981	1982	1983	1984	1985
Bus & Trackless Trolley Average Fare	40.3¢	36.3¢	39.7¢	40.3¢	38.3¢
Green Line Average Fare	41.7¢	33.7¢	37.4¢	40.6¢	40.3¢
Total Surface Trips	422,125	427,276	442,470	457,213	455,419
Average Fare	39.9¢	37.1¢	37.6¢	38.2¢	37.9¢
Rapid-Transit Trips	305,699	355,581	347,514	380,779[1]	396,674
Average Fare	60.0¢	50.4¢	51.0¢	-	51.9¢
Linked Trips	490,900	513,500	531,760	565,898	576,843
Average Fare	71.1¢	63.5¢	64.1¢	64.6¢	64.9¢

[1]Because a rapid-transit survey was not conducted in 1984, rapid-transit trips were estimated by applying the 1983 average fare to 1984 revenue.

1985 MBTA Fare-Mix Sampling Program

Technical Report 57
January 1987

SUMMARY OF 1981-1985
MBTA FARE-MIX
SAMPLING PROGRAM RESULTS

CTPS

TABLE
1-1

2 MBTA TRANSIT SERVICE

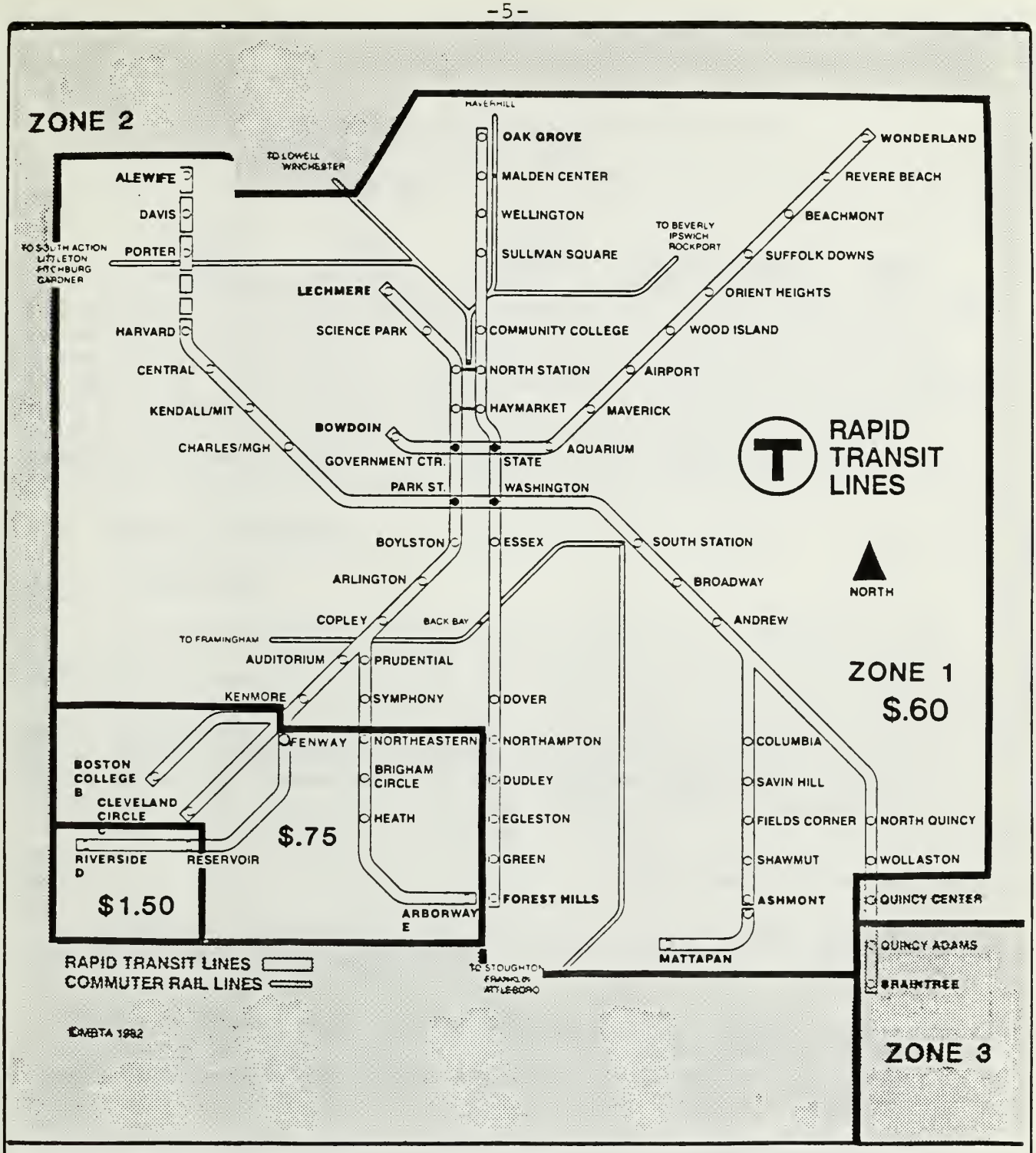
As of 1985, when the new data for this report were collected, the MBTA operated bus routes, trackless-trolley routes, five light-rail branches (the Green Line and the Mattapan High-Speed Line), three rapid-transit routes, and commuter rail. All but commuter rail are covered in this report. The Green Line is a combination of low-platform streetcar service on the surface and rapid-transit or subway service in the downtown and Back Bay areas. Figure 2-1 is a map of the transit system, showing fares by zone; Table 2-1 presents the fare tariff for the bus system.

The MBTA employs a zoned fare structure. The basic adult cash fares are sixty cents for rapid transit and for subway Green Line service, and fifty cents for trackless-trolley and local bus service. The rapid-transit lines are divided into three zones, with the maximum one-way trip at $1.20. There are zoned fares on some local bus routes and a range of fares on express-bus routes. Fares on the surface portion of the Green Line are paid in the inbound direction only and range from seventy-five cents to a dollar and a half.

The MBTA also offers a number of discount and reduced fares to eligible riders. Riders can purchase a variety of pre-paid monthly passes which have no limit on the number of times that they can be used. The elderly (65 and over) pay a ten-cent fare at all times, except for express and zoned bus trips beyond the local area, for which they pay one-half the adult fare. The handicapped pay the full adult fare for peak-period travel (7:00-9:00 A.M. and 4:00-6:00 P.M. weekdays) and the elderly fare at all other times. In 1986 this was changed so that the elderly fare applies to the handicapped at all times. Children between five and twelve pay half-fare at all times. Students in kindergarten through twelfth grade pay half-fare during school hours if they have proper identification. Students can also obtain monthly passes from their schools.

All fares are paid as passengers board buses and trolleys and as they enter rapid-transit stations. Passengers also pay an additional fare as they leave the Zone 3 rapid-transit stations (Quincy Adams and Braintree). In rapid-transit stations, tokens are deposited before passengers pass through the regular, full-fare turnstiles. At least two turnstiles per station are equipped to read electronically the pre-paid passes (not including student passes). Those who pay reduced fares or no fare are sup-

posed to use turnstiles at the collector's booths (referred to as collector's turnstiles in this report). "Gateman's boxes," which allow passengers paying any type of fare to pass through, are open in several stations (primarily at peak travel times).



ZONE 1 - $.60 - $.30 - $.10
ZONE 2 - $.90 - $.45 - $.10
ZONE 3 - $1.20 - $.60 - $.10
ADULT STUDENT & CHILDREN ELDERLY

1985 MBTA Fare-Mix Sampling Program	RAPID-TRANSIT NETWORK AND ZONAL FARES (1985)	CTPS
Technical Report 57 January 1987		FIGURE 2-1

Zone	Route Miles*	Adult Fare**	Student & Child Fare	Elderly Fare
1	0 - 6	$0.50	$ .25	$ .10
2	6 - 9	0.75	.35	$ .35
3	9 - 12	1.00	.50	.50
4	12 - 15	1.25	.60	.60
5	15+	1.50	.75	.75

*Zone fares may be adjusted based on geographic, topographic, or other distinctive circumstances in order to establish logical boundaries.

**NOTES ON ADULT FARE:

- Base Fare - $0.50, good for all routes that are less than 6 miles and for the first 6-mile zone on routes longer than 6 miles.
- Zone Fares - Additional $0.25 for each 3-mile increment.
- Express Premium - Additional $0.25 for express-bus services.
- Maximum Fare - $1.50, including express premium.

3 CHANGES IN TRANSIT SERVICE AND FARE BETWEEN 1981 and 1985

It is important to realize that apparent increases or decreases in transit ridership between 1981, 1982, 1983, and 1984 in several categories can, in part, be attributed to transit-service or -fare changes. For example, in December 1982, the revoking of the elderly-and-handicapped off-peak free fare had an impact on surface-transit ridership. In addition, refinements to survey and data-analysis techniques have influenced survey results. Attempts have been made in this section and the next to point out these differences and how they affect the data.

3.1 SERVICE CHANGES

3.1.1 1981-1984

In November 1981, when the first fare-mix survey was conducted, the Dorchester Branch of the Red Line (between Columbia and Ashmont stations) and the Mattapan High-Speed Line were not in service because new track was being laid. The people who normally used these portions of the system were bused to Andrew or North Quincy stations. The token turnstiles at these stations, particularly Andrew, were not designed to handle the increased passenger load during the A.M. and P.M. peaks. Therefore, many of those who used tokens and prepaid passes, as well as those who paid cash, went through the collectors' turnstiles and the open gates that were monitored by gatemen. This resulted in uncharacteristically high figures for use of the collector's turnstiles and gateman's boxes. It should also be pointed out that the 1981 sample did not include those who made local trips on the substitute bus service for the Dorchester Branch.

The Arborway Branch of the Green Line was also not in operation during November 1981. Inbound Arborway users were bused to Copley Station, where they went through gates without paying an additional fare, thereby influencing gate counts at Copley. Service was restored on this branch in June 1982. The addition of Arborway riders in the 1982 sample of the surface Green Line influenced the average fare for the Green Line.

Rapid-transit service in 1983 was the same as in 1982, with two exceptions. On September 3, 1983, Quincy Adams Station opened. This station is located between Quincy Center and Braintree stations on the southern extension of the Red Line.

At the other end of the Red Line, the Harvard/Brattle and Harvard/Holyoke stations were closed in September 1983, and all passengers began using Harvard Station. On surface transit, a few new routes were added and some changes were made to existing routes between 1982 and 1983; overall, these changes did not alter the character of the system.

Rapid-transit service and surface-transit service remained essentially the same in 1984. While Porter and Davis stations were opened in December 1984, the openings took place after the close of the sampling period.

3.1.2 1985

The Red Line extension was completed in March of 1985 with the opening of Alewife Station. Some surface transit routes were added or rerouted as a result of the station opening. Evening shuttle-bus service was instituted to accommodate track reconstruction on the Green Line and the Red Line.

3.2 FARE CHANGES

3.2.1 1981-1983

The base rapid-transit fare was seventy-five cents in November 1981. It was reduced to sixty cents in May 1982. Student passes were available only for bus trips during 1981. Boston public-school students who used rapid transit were issued tokens at thirty-five cents apiece. Beginning in September 1982, student passes were available, which could be used on either mode. The base fare for surface transit did not change between 1981 and 1982.

The basic adult fare for surface transit and rapid transit did not change from 1982 to 1983. The free off-peak elderly fare (9:30 A.M.-4:00 P.M., Monday-Friday), with half-fare for the elderly at all other times, was replaced by a ten-cent fare at all times, except for express bus, zoned bus beyond the local area, and commuter rail. This fare change resulted from a bill passed by the legislature that became effective on December 20, 1982.

3.2.2 1984-1985

There were no fare changes for surface transit or rapid transit in any category during 1984 and 1985.

4 SAMPLING TECHNIQUES AND DATA-COLLECTION PROCEDURES

4.1 OVERVIEW

Ridership is estimated from revenue using an average fare determined from the fare mix. The sampling program was designed to find the fare mix. Sampling techniques for 1985 surface and rapid transit are essentially the same as those used in past years.

The average fare can be calculated as follows:

$$F_a = (F_f \times P_f) + (F_r \times P_r)$$

where F_a = average fare
F_f = full fare
F_r = reduced fare
P_f = % passengers who pay full fare
P_r = % passengers who pay reduced fare

The degree of precision or confidence interval of the average fare can be calculated as follows:

$$\pm [(CIP_f \times F_f) + (CIP_r \times F_r)]$$

where CIP = confidence interval of the fare mix for P_f and P_r, respectively

For the purposes of the sampling program, the confidence interval of the fare mix was set at $\pm$2.5 percent and the confidence level (allowable degree of risk) at 95 percent. These parameters mean that the probability of the estimated fare mix differing by more than 2.5 percent from the actual fare mix is one in twenty.

To determine the fare mix, the least complicated sampling technique available was the simple random sample, wherein each item or individual had an equal chance of being selected. The number of observations (or the size) for this type of sample is determined by the confidence interval, the confidence level, and the nature of the results required (in this connection, seen in terms of proportions of riders). The formula used to calculate the sample size was the following:

$$No = pq \frac{t^2}{d^2}$$

where No = the required sample size
p = the unknown proportion

q = the remaining proportion
d = the interval size
t = the statistic which relates the confidence level to the normal curve

The "unknown" and "remaining" proportions correspond, respectively, to the percentage of riders who pay full adult fare and the percentage who pay other than full fare. For the purpose of calculating sample size, these proportions were estimated to be fifty/fifty, which produced the largest possible proportions. (Note that of all possible proportions, fifty/fifty is always most conducive to a large sample size.) Using the given parameters, the formula yields a sample size of 1,536, which was rounded to 1,540.

After the sampling program was completed, actual confidence intervals obtained were calculated by using the formula

$$\pm \; a \sqrt{\frac{P_s Q_s}{N}}$$

where a = coefficient of confidence level
P_s = sampling proportion
Q_s = the remaining proportion
N = the number of observations

For example, if 1,600 passengers were counted and the following data were obtained:

Fare mix: Full fare = 65% (P_f)
Reduced fare = 25% (P_r)
Free = 10%

Fare: Full fare = 60¢
Reduced fare = 30¢

then the confidence interval of the fare mix at a 95-percent confidence level would be:

$$\underline{\text{Full fare}} = 1.96 \times \sqrt{\frac{.65(.35)}{1,600}} = \pm 2.34\%$$

or 65% $\pm$ 2.34% = 62.66% to 67.34%

$$\underline{\text{Reduced fare}} = \pm 1.96 \times \sqrt{\frac{.25(.75)}{1,600}} = \pm 2.12\%$$

or 25% $\pm$ 2.12% = 22.88% to 27.12%

The average fare would be:

(60¢ x .65) + (30¢ x .25) = 46.5¢

and the confidence interval of the average fare would be:

$$(.0234 \times .60) + (.0212 \times .30) = 2.04¢$$

$$\text{or } 46.5¢ \pm 2.04¢ = 44.5¢ \text{ to } 48.5¢$$

4.2 SURFACE TRANSIT (BUS, TRACKLESS TROLLEY, AND SURFACE GREEN LINE)

4.2.1 Bus and Trackless Trolley, 1981-1984

Surface-transit revenue is calculated by district; therefore, a sample was drawn from each one during Period 5 of each year. Within a given district, a driver's daily duty assignment is called a "run," which includes trips on one or several routes. It was decided that the bus-and-trackless-trolley sample should be based on runs, since the people doing the counts could then be assigned to a driver for a day and not have to worry about making connections with other vehicles. Note that the use of runs may not always insure an unbiased estimate for the population as a whole; however, given constraints on time and resources, it is the most efficient method available.

The number of runs sampled per district was pro-rated according to the proportion of district runs to total runs. The resulting number of runs to be sampled per district ranged from 2 to 12 for the weekday sample and from 3 to 5 for the weekend sample in 1981 and 1982. (The total number of runs sampled was determined through estimating the average number of passengers per trip.) In 1983, because of manpower constraints during November, it was necessary to reduce the number of runs sampled. This could be done without a loss in statistical significance, since four out of the seven districts were over-sampled in previous years. Results were weighted according to the number of daily scheduled runs by district. The number of weekday sampled runs per district ranged from two to six. Two runs from each district were sampled on Saturday and one run on Sunday. Since the reduced sample size produced reliable results in 1983, approximately the same number of runs was sampled in 1984. An additional two runs were sampled in response to the recommendation that samples from the smaller districts be increased. All runs for each year were listed by district and the selections were made by using a random-numbers table.

Only one traffic checker per run was needed to collect data for the bus-and-trackless-trolley sample. He sat behind the driver and recorded the number of people boarding and the type of fare paid (adult full-fare, student pass, etc.), farebox readings, and other pertinent information.

4.2.2 Bus and Trackless Trolley, 1985

In mid-1985, the MBTA began a data-collection program to gather data needed for its own planning purposes and to satisfy Section 15 federal reporting requirements. It was determined that a random sample of 208 one-way trips on which boardings and alightings were counted by stop would provide statistically significant data. (Section 15 results are included in Appendix 4.)

Since the sample was selected on a trip-by-trip basis, the checker would have nothing to do on the return trip. The MBTA, therefore, decided that it would be more cost-effective to collect fare-mix data in that direction. A random sample of trips to be surveyed was selected from each month from June through December rather than from Period 5 only (Table A-2a in Appendix 2 lists the selected trips).

4.2.3 Surface Green Line, 1981-1984

For the surface Green Line, in 1981, a simple random sample of runs was selected at the Reservoir Garage, from which Green Line cars are dispatched. Traffic checkers were assigned to specific runs, which meant that they had to stay on a particular car until their shifts ended. They counted people boarding inbound on the surface portion, recorded the type of fare paid, and recorded surface revenue; then they rode underground to the end of the line, rode back in the outbound direction, and counted people boarding outbound on the surface (no fares are collected). Among the problems encountered were frequent farebox malfunctions, which meant that sometimes there was no revenue figure (and therefore no average fare) for an entire run. The procedure was confusing to the checkers and they frequently failed to count those boarding in the outbound direction. Even though a portion of the survey was conducted a second time, some faulty data were still obtained.

In 1982, it was decided that the sample of the surface Green Line should be based on trips instead of runs. The 1978 system-wide survey was used to determine the minimum number of inbound trips that had to be surveyed per time period, by branch. The same number of outbound trips per period also had to be surveyed. The first A.M. inbound trip to be boarded by a given checker on a given survey day was selected randomly (from trips before 6:05 A.M.). The checker rode in on that trip, got off at Kenmore (Symphony on the Arborway branch), and got on the next outbound car on the branch to which he had been assigned. Therefore, if a car had a faulty farebox meter, only one, rather than a series, of surveyed trips had unusable data. The 1982 outbound count was much more accurate than that of 1981. Although the data show an increase in outbound ridership, the nature of the changes between the two years is unclear, given the inaccuracy of the 1981 data.

The surface 1983 Green Line survey was conducted in a manner similar to that of 1982. Once again, it was necessary to reduce the number of trips sampled. The inbound starting time for a given checker was the same as in 1982. After riding in on that trip and disembarking at Kenmore, a checker could then get on the next outbound car on any line. Results were weighted based on the number of scheduled trips per line.

The method for the 1984 surface Green Line survey remained the same as in 1983, with more trips surveyed than in 1983. A total of 96 weekday trips were sampled in 1984--compared to 84 in 1983. Corresponding weekend trips were 108 in 1984 and 100 in 1983. The variation in the number of surveyed trips resulted from the necessity of maintaining the appropriate number of trips per line by time of day (see Table 4-1). Again, the results were weighted according to the number of scheduled trips per line.

4.2.4 Surface Green Line, 1985

The sampling method for the 1985 surface Green Line was identical to that of 1984 and 1983, and the results were weighted as in previous years. Table A-2b in Appendix 2 shows the surface-Green-Line survey schedule in detail. It should be noted that the sampling period (Period 5) remained the same as in previous years, unlike that for buses and trackless trolleys, which extended over six revenue periods.

4.3 RAPID TRANSIT

4.3.1 1981-1984

At rapid-transit stations, only collector's turnstiles and gateman's boxes required manual counting. The regular turnstiles, when functioning properly, provide the necessary data on token and prepaid-pass usage. Traffic checkers recorded the number of people passing the gateman's boxes, by method of fare payment. They recorded turnstile readings at the collector's turnstiles (and at the regular turnstiles, as a back-up to the data provided by the MBTA).

During an average weekday, 13 percent of all rapid-transit users passed through collector's turnstiles at 54 stations. For each station, the proportions of riders using the collector's turnstiles to total riders system-wide using the collector's turnstiles, in each of four time periods, were calculated. These proportions were listed in a table on a station-by-time-period basis and organized into four groups, three of which represented roughly equal percentages of the total. Only a minor proportion of passengers was accounted for in the fourth group; therefore, it was decided that it would be inefficient to sample that group. It was initially determined that 1,500 passengers should be sampled from each group, but, when the fourth group was eliminated, the sample size was increased for each of the other

DISTRIBUTION OF INBOUND SURFACE-GREEN-LINE BOARDINGS BY BRANCH AND TIME PERIOD*

	Riverside	Boston College	Cleveland Circle
6:00-9:00 A.M.	36.0%	27.2%	35.8%
9:00-3:00 P.M.	36.1	46.6	42.0
3:00-6:00 P.M.	21.3	20.5	16.5
6:00-Midnight	6.6	5.7	5.8
Total	100.0%	100.0%	100.1%

MINIMUM INBOUND TRIPS TO BE SURVEYED PER PERIOD**

	Riverside	Boston College	Cleveland Circle	Arborway
6:00-9:00 A.M.	3	3	3	2
9:00-3:00 P.M.	3	4	3	3
3:00-6:00 P.M.	2	2	1	1
6:00-Midnight	1	1	1	1
Total	9	10	8	7

*Source: 1978 Systemwide Survey

**Arborway was not surveyed in 1978; however, it was felt that the Arborway ridership profile closely resembles that of the Cleveland Circle Branch.

groups, and cells were drawn from the first, second, and third groups equally.

In 1982, as in 1981, a relatively small number of rapid-transit stations had gateman's boxes that were authorized to be open, so all of these were counted. However, it was discovered that gates at many stations were open unofficially. Therefore, a random sample of these was selected for counting.

The number of rapid-transit stations at which collector's turnstiles were sampled was reduced from 29 to 23. The starting point for making the selection was 1982 station choices. Stations were deleted so as to maintain a sample representative of the three station groups described above in this section. Gateman's boxes at rapid-transit stations were also sampled. No sample was taken at unofficial gates in 1983; 1982 survey results were used for this component of the analysis.

Collector's turnstiles and gateman's boxes were not surveyed in 1984. Given the slight variation in fare mix and average fare between 1982 and 1983 and constraints on time and personnel, it was decided that a rapid-transit survey need only be conducted every other year and that average fare and fare mix could be assumed to be the same in 1984 as in 1983.

4.3.2 1985

The 1985 sampling procedure was identical to that of 1983 (there was no rapid-transit survey in 1984).

5 DATA-ANALYSIS PROCEDURES AND RESULTS

The following discussion summarizes the data analysis and results of the Fare-Mix Sampling Program for unlinked and linked trips. A more detailed explanation of the data-analysis procedures is given in Appendix 1.

For the purpose of this survey, an unlinked surface trip is defined as a trip made using one surface vehicle, and an unlinked rapid-transit trip is defined as a trip made on the rapid-transit system (including the underground portion of the Green Line) and can include transfers from one rail-transit line to another. A linked trip is defined as one trip from origin to destination regardless of the transfer required. For example, if one were to ride a bus from near one's home to a rapid-transit station and there board the subway for the remainder of the trip to work, these two unlinked trip would result in one linked trip.

5.1 UNLINKED TRIPS

5.1.1 Surface Transit (Surface Green Line, Buses, and Trackless Trolleys)

- Data-Analysis Procedure

The data used to estimate the average fare were obtained from a survey of the surface portions of the Green Line and selected bus and trackless-trolley routes. Traffic checkers counted passengers and recorded their method of fare payment and the fare-box readings. In previous years, bus data were collected in Period 5 only. In 1985, however, bus data were collected over six periods. In order to produce results consistent with previous years, the survey fare mix and average fare were applied to Period 5 revenue only rather than to an average of the six revenue periods. This year, as in other years, Green Line data were collected in Period 5 only.

- Results

In Table 5-1 the fare mix and average fare for the surface portion of the Green Line are presented. Between the 1981 and 1982 survey periods, the average fare decreased by 8¢, from 41.7¢ to 33.7¢. In 1983, the average fare was 37.4¢, 3.7¢ higher than in the 1982 survey period. In 1984, the average fare increased by 3.2¢, from 37.4¢ to 40.6¢. The 1985 average fare of 40.3¢ is virtually identical to that of 1984.

		1981	1982	1983	1984	1985
Fare Mix						
Adult	- Cash	38.4%	29.6%	31.1%	31.9%	34.5%
	- Pass	25.3	27.4	28.0	27.7	30.9
Elderly & Handicapped	- Free	5.9	3.6	-	-	-
	- 1/2 Fare	1.6	0.9	-	-	-
	- Reduced	-	-	7.3	4.1	5.8
Students & Children	- 1/2 Fare	1.1	1.5	1.5	1.2	1.7
	- Pass	0.2	0.1	0.8	0.8	0.7
Free	- Authorized	27.0	36.9	31.2	34.3	26.4
	- Unauthorized	0.0	-	0.1	0.0	-
		100.0%	100.0%	100.0%	100.0%	100.0%
Average Fare[1]		41.7¢	33.7¢	37.4¢	40.6¢	40.3¢
Confidence Interval of Average Fare						
		N.A.	±1.0¢	±1.2¢	±1.5¢	±1.3¢

[1]The average fare represents the weighted average of the four components of the surface Green Line and does not include pass revenue.

1985 MBTA Fare-Mix Sampling Program	SURFACE-GREEN-LINE FARE MIX 1981-1985 (WEEKDAY)	CTPS TABLE 5-1
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The bus and trackless-trolley fare mix and average fare are presented by year in Table 5-2. In previous years, the fare mix and average fare were given by garage. The 1985 sample, however, was not selected by garage. Therefore, for most individual garages, not enough data were collected to provide a confidence interval of ± 2.5 percent at a 95-percent confidence level. The table shows that with the exception of 1982, the average fare and fare mix for the bus system as a whole have been very consistent.

The decrease in the average fare between 1981 and 1982 cannot be explained for surface transit, as it can be for rapid transit, by a change in the fare structure. The free off-peak elderly fare, instituted in late 1981, affected a small proportion of total riders. It may have resulted in a slight reduction in the average fare, but not a reduction of the magnitude indicated by the survey results. Similarly, the increase in the average fare between 1982 and 1983 cannot be explained by the replacement of the off-peak elderly fare with a ten-cent fare in effect at all times. It is difficult to determine the actual reasons for the low estimated average fare in 1982.

The 1985 average fare is somewhat lower than those of the two previous years. This is partially due to what appears to be an increase in the reduced fare categories. There is also an unexplained increase in the authorized free category. It is possible that the change in the survey period from a sample of Period 5 only to a sample of six revenue periods has affected bus and trackless trolley results.

To produce a composite estimate of the surface-transit fare mix and average fare, weights in accordance with the percentage of total surface ridership were applied to the surface-Green Line, trackless-trolley, and bus fare mixes. The results are presented in Table 5-3. The fare mix has been fairly constant from year to year.

In Table 5-4, the number of estimated trips, the average fare, and other summary data are presented for surface transit for 1981 through 1985. The table shows annual increases in revenue from 1981 through 1985 except in 1982. The slight decline in surface ridership in 1985 is most likely a result of a shift from buses to rapid transit at Alewife, Porter, and Davis stations.

5.1.2 Rapid Transit

- Data-Analysis Procedure

Token and passmeter readings and the amount of cash taken in at the various booths are recorded daily for rapid transit by the MBTA. These data, augmented with sample data from the survey of collector's turnstiles and gateman's boxes and additional revenue data from the MBTA, were used to estimate average fare and

		1981	1982	1983	1984	1985
Fare						
Adult	- Cash	39.1%	35.1%	36.7%	36.1%	34.6%
	- Pass	33.3	34.7	33.2	35.9	30.7
Elderly & Handicapped	- 1/2 Fare	5.2	3.8	-	-	-
	- Free	7.2	11.9	-	-	-
	- Reduced	-	-	11.9	13.0	14.6
Students & Children	- 1/2 Fare	11.4	9.3	13.0	9.7	13.3
	- Pass	2.9	4.2	4.5	4.3	4.6
Free	- Authorized	0.5	0.9	0.5	.9	2.1
	- Unauthorized	0.4	0.0	0.0	0.1	0.1
		100.0%	100.0%	100.0%	100.0%	100.0%
Average Fare[1]		40.3¢	36.3¢	39.7¢	40.1¢	38.3¢
Confidence Interval of Average Fare						
		N.A.	±.6¢	±.7¢	±.9¢	±1.2¢

[1]Does not reflect pass revenue.

1985 MBTA Fare-Mix Sampling Program	BUS AND TRACKLESS-TROLLEY FARE MIX 1981-1985 (WEEKDAY)	CTPS TABLE 5-2
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		1981	1982	1983	1984	1985
Fare Mix						
Adult	- Cash	36.9%	34.9%	36.4%	36.6%	35.4%
	- Pass	30.7	32.6	31.4	33.2	30.2
Elderly & Handicapped	- Free	6.3	8.9	-	-	-
	- 1/2 Fare	5.3	4.3	-	-	-
	- Reduced	-	-	11.0	11.1	13.0
Student & Children	- 1/2 Fare	9.9	7.4	9.3	7.4	10.0
	- Pass	2.3	2.9	3.1	2.7	3.4
Free	- Authorized[1]	5.4	9.0	8.7	9.0	7.8
	- Unauthorized	0.5	-	-	-	0.2
		100.0%	100.0%	100.0%	100.0%	100.0%
Average Fare[2]		41.1¢	36.7¢	39.1¢	40.9¢	38.2¢

[1] Includes passengers riding free in the outbound direction on the surface Green Line.

[2] Does not include pass revenue.

1985 MBTA Fare-Mix Sampling Program	WEIGHTED SURFACE-TRANSIT FARE MIX 1981-1985 (WEEKDAY & WEEKEND)	CTPS TABLE 5-3
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	1981	1982[1]	1983	1984	1985
Unlinked Average Weekday Trips					
Pass	139,301	147,410	152,652	164,139	153,021
Cash	282,824	279,866	289,818	293,074	302,398
Total	422,125	427,276	442,470	457,213	455,419
Survey-Period Revenue	$3,656,678	$3,451,370	$3,614,588	$3,797,712	$3,883,153
Average Fare	39.6¢	37.1¢	37.6¢	38.2¢	37.9¢
Pass Sales (Nov)	58,184	62,697	70,164	71,915	74,412
Uses per Pass/ Period	53	51	48	51	47

[1] Revised

1985 MBTA Fare-Mix Sampling Program	SURFACE-TRANSIT SUMMARY 1981-1985	CTPS
Technical Report 57 January 1987		TABLE 5-4

unlinked rapid-transit trips. Some adjustments to the data on tokens were made, because turnstiles at Quincy Center, Quincy Adams, and Braintree require more than one token. Adjustments were also made to passmeter readings for missing or inaccurate data due to broken meters.

- Results

The estimated rapid-transit fare mix, average fare, and number of unlinked trips for 1981-1985 are presented in Table 5-5. The number of unlinked rapid-transit trips increased by 9.8 percent between 1981 and 1982, by 3.6 percent between 1982 and 1983, and by 14.1 percent between 1983 and 1985. Much of the substantial increase between 1981 and 1982 can be explained by a fare decrease of 15 cents. The increase between 1983 and 1985 is due, in part, to the opening of the Alewife Extension on the Red Line. The average fare has not fluctuated substantially since the fare decrease in 1982.

5.2 LINKED TRIPS

5.2.1 Data-Analysis Procedures

In order to link rapid-transit and surface trips, an estimate of the proportion of rapid-transit-only, surface-only, and combination (rapid transit and surface) trips is needed. For this year's analysis, as for 1982 through 1984, the source used was the 1978 System-wide Survey, which included a question about transfer behavior. Because of service cuts, fare increases, and transit-line extensions that took place after that survey was taken, 1981 proportions were changed slightly to 31-percent rapid-transit-only, 30-percent surface-only, and 39-percent combination. By November 1982, however, much of the cut service had been restored, and rapid-transit and pass fares had been reduced. Therefore, the 1978 proportions of 29 percent, 31 percent, and 40 percent, respectively, were thought to be more appropriate.

The actual process for linking trips for 1982 was not the same as that used in 1981, because it was thought that the accuracy of the 1981 process could be improved by assuming that the proportion of combination trips is more accurate than the individual surface-only and rapid-transit-only proportions. Simultaneous equations were used to find the total number of combination trips, which was then subtracted from total unlinked rapid-transit trips and total unlinked surface trips to find rapid-transit-only and surface-only trips. This method has remained in effect for 1983-1985. The 1981 trips were re-linked using the new method so that the results would be compatible with those of subsequent years.

		1981	1982	1983	1985[1]
Fare Mix					
Adult	- Cash	48.5%	49.9%	48.6%	50.3
	- Pass	29.2	32.3	32.3	34.8
Elderly & Handicapped	- Free	11.1	8.9	NA	NA
	- 1/2 Fare	3.8	3.2	NA	NA
	- Reduced	NA	NA	13.5	11.0
Students & Children	- 1/2 Fare	5.8	1.9	1.6	2.5
	- Pass	NA	2.9	3.3	-
Free	- Authorized	1.2	0.8	0.5	1.0
	- Unauthorized	0.4	0.2	0.2	-
		100.0%	100.0%	100.0%	100.0%
Average Fare		60.0¢	50.4¢	51.0¢	51.9¢
Total Unlinked Trips (Average Weekday)[2]		305,000	335,581	347,514	396,539

NA = not applicable

[1]Rapid-transit fare mix was not sampled in 1984

[2]Includes pass trips

1985 MBTA Fare-Mix Sampling Program	RAPID-TRANSIT FARE MIX 1981-1985 (WEEKDAY)	CTPS
Technical Report 57 January 1987		TABLE 5-5

5.2.2 Results

Table 5-6 provides a summary of average-fare and ridership calculations from 1981 through 1985. The average fare decreased from 71.1¢ in 1981 to 63.5¢ in 1982, while there was an increase of 4.6 percent in the number of average-weekday linked trips (from 490,900 in 1981 to 513,500 in 1982). In 1983 the number of linked trips was 531,760, an increase of 3.6 percent over 1982, and the average fare was 64.1¢.

In 1984, the number of linked trips was 565,898, 6.4 percent higher than in 1983, and the average fare was 64.6¢. The increase in linked trips in 1984 over 1983 was much larger than in other years; however, it should be noted that 1984 linked trips were calculated using a figure for rapid-transit unlinked trips that was estimated by applying the 1983 average fare to 1984 revenue data. This was necessary because no rapid-transit survey was conducted in 1984. It should also be noted that some changes in revenue-collection practices (to insure against losses) in May 1984 may affect comparisons of revenue/ridership figures before and after that date.

In 1985, there were 576,843 average-weekday linked trips, an increase of 1.9 percent over 1984. The average fare was 64.9¢. The calculations for 1985 linked trips are summarized in Appendix 1, Part III.

Unlinked Average Weekday Trips					
Rapid Transit	1981	1982	1983	1984[1]	1985
Token	141,759	155,255	157,143	-	191,541
Pass - Passmeter	(77,044)	(87,647)	(90,116)	-	(99,814)
- Passholders using gates or collector's turnstiles	(13,301)	(22,581)	(29,876)	-	(38,231)
Subtotal	90,345	110,228	119,992	-	138,045
Cash	73,595	70,128	70,379	-	67,088
Total	305,699	335,581	347,514	380,779[2]	396,674
Survey-Period Revenue	$3,932,827	$3,636,496	$3,797,495	$4,128,347	$4,540,907
Average Fare	60.0¢	50.4¢	51.0¢	-	51.9¢
Pass Sales (November)	50,432	60,053	64,894	70,147	76,542
Uses per Pass/Period	38	39	37	-	36
Surface Transit	1981	1982	1983	1984	1985
Pass	139,301	147,410	152,652	164,139	153,021
Cash	282,824	279,866	289,818	293,074	302,398
Total	422,125	427,276	442,470	457,213	455,419
Survey-Period Revenue	$3,656,678	$3,451,370	$3,614,588	$3,797,712	$3,883,153
Average Fare	39.6¢	37.1¢	37.6¢	38.2¢	37.9¢
Pass Sales (November)	58,184	62,697	70,164	71,915	74,412
Uses per Pass/Period	53	61	48	51	47
Linked Trips per Average Weekday	490,900	513,500	531,760	565,898	576,843
Average Fare	71.1¢	63.5¢	64.1¢	64.6¢	64.9¢

[1] A rapid-transit survey was not conducted in 1984.
[2] Estimate calculated by applying 1983 average fare to 1984 revenue.

1985 MBTA Fare-Mix Sampling Program Technical Report 57 January 1987	SUMMARY OF 1981-1985 AVERAGE-FARE AND RIDERSHIP CALCULATIONS	CTPS TABLE 5-6

6 STATISTICAL ANALYSIS

The estimated average fare mix can be used to estimate boardings within a confidence interval of ±2.5 percent.

The actual confidence intervals at a 95-percent confidence level and sample sizes for the bus system, the Green Line, and collectors' turnstiles are presented in Tables 6-1, 6-2, and 6-3. Except for the weekend bus fare mix, the confidence intervals are less than ±2.5 percent.

	Weekday		Weekend	
	Number Counted	Confidence Interval	Number Counted	Confidence Interval
Adult Cash	1270	±1.15%	307	±3.38%
Adult Pass	1128	±1.49%	205	±3.03%
E&H Reduced Fare	537	±1.14%	193	±2.97%
Student & Children 1/2 Fare	487	±1.1%	55	±1.76%
Student Pass	171	±0.68%	-	-
Authorized Free	78	±0.46%	28	±1.27%
Unauthorized Free	3	-	9	±0.72%
Total	3674		797	

*95% confidence level

1985 MBTA Fare-Mix Sampling Program	ACTUAL CONFIDENCE INTERVALS* BUS & TRACKLESS TROLLEY	CTPS
Technical Report 57 January 1987		TABLE 6-1

	Weekday		Weekend	
	Number Counted	Confidence Interval	Number Counted	Confidence Interval
Adult Cash	2,723	±1.05%	2,171	±1.31%
Adult Pass	2,441	±1.02%	1,464	±1.18%
E&H Reduced Fare	456	±0.51%	344	±0.65%
Student and Children 1/2 Fare	132	±0.28%	107	±0.37%
Student Pass	57	±0.17%	-	-
Authorized Free	2,090	±0.97%	1,315	±1.14%
Unauthorized Free	-	-	-	-
TOTAL	7,899		5,402	

*95% confidence level

1985 MBTA Fare-Mix Sampling Program	ACTUAL CONFIDENCE INTERVALS* SURFACE GREEN LINE	CTPS TABLE 6-2
Technical Report 57 January 1987		

	Weekday		Weekend	
	Number Counted	Confidence Interval	Number Counted	Confidence Interval
Adult Cash	144	±1.62%	1,250	±1.79%
Adult Pass	144	±1.62%	1,445	±2.27%
E&H Reduced Fare	766	±2.62%	482	±2.26%
Student and Children 1/2 Fare	176	±1.76%	292	±1.90%
Student Pass	46	±0.94%	-	-
Authorized Free	101	±1.37%	113	±1.26%
Unauthorized Free	-	±0.30%	9	± .38%
TOTAL	1,377		1,591	

*1983 survey results at a 95% confidence level

1985 MBTA Fare-Mix Sampling Program	ACTUAL CONFIDENCE INTERVALS* COLLECTOR'S TURNSTILES	CTPS TABLE 6-3
Technical Report 57 January 1987		

7 SUMMARY AND RECOMMENDATIONS

7.1 SUMMARY

The purpose of the annual fare-mix survey is to provide current data on the type of fare paid by a sample of transit riders. From this information is derived an average fare, which, combined with revenue data, is used to estimate daily ridership.

For the purpose of the survey, the MBTA system is divided into three sections: surface transit, rapid transit, and the surface portions of the Green Line. MBTA checkers surveyed trips from each component to provide separate estimates of average fare and unlinked ridership. These figures are combined to produce an estimate of linked trips and an estimated average fare.

The results of the analyses show that linked trips have increased from 1981 through 1985 and that the linked average fare has been fairly constant since 1983.

7.2 RECOMMENDATIONS

The following points should be taken into consideration in planning and implementing all future surveys.

- The bias in the 1982 survey toward the elderly-and-handicapped fare category may be the result of a large proportion of the survey taking place during off-peak times, when the free elderly fare was in effect (it has not been ascertained whether this proportion of the surveying was in fact large). If another time-related fare category is instituted in the future, this type of bias may again be an issue. To avoid the problem, the time of day should be controlled in the survey.

- The mechanical condition of transit-system data-collection devices continues to be a problem during the implementation of a survey, as well as at other times. There should be an ongoing program of regular maintenance to ensure that accurate data are obtained throughout the year, particularly at rapid-transit stations.

- Data collectors should be extremely careful when recording information that forms the basis for the entire analysis.

- The results of the 1986 Green Line Study conducted by CTPS, rather than the 1978 Systemwide Survey, should be used to determine the distribution of boardings and trips to be surveyed on the Green Line for future fare-mix programs.

APPENDIX 1

Annotated* Flow Diagram

of

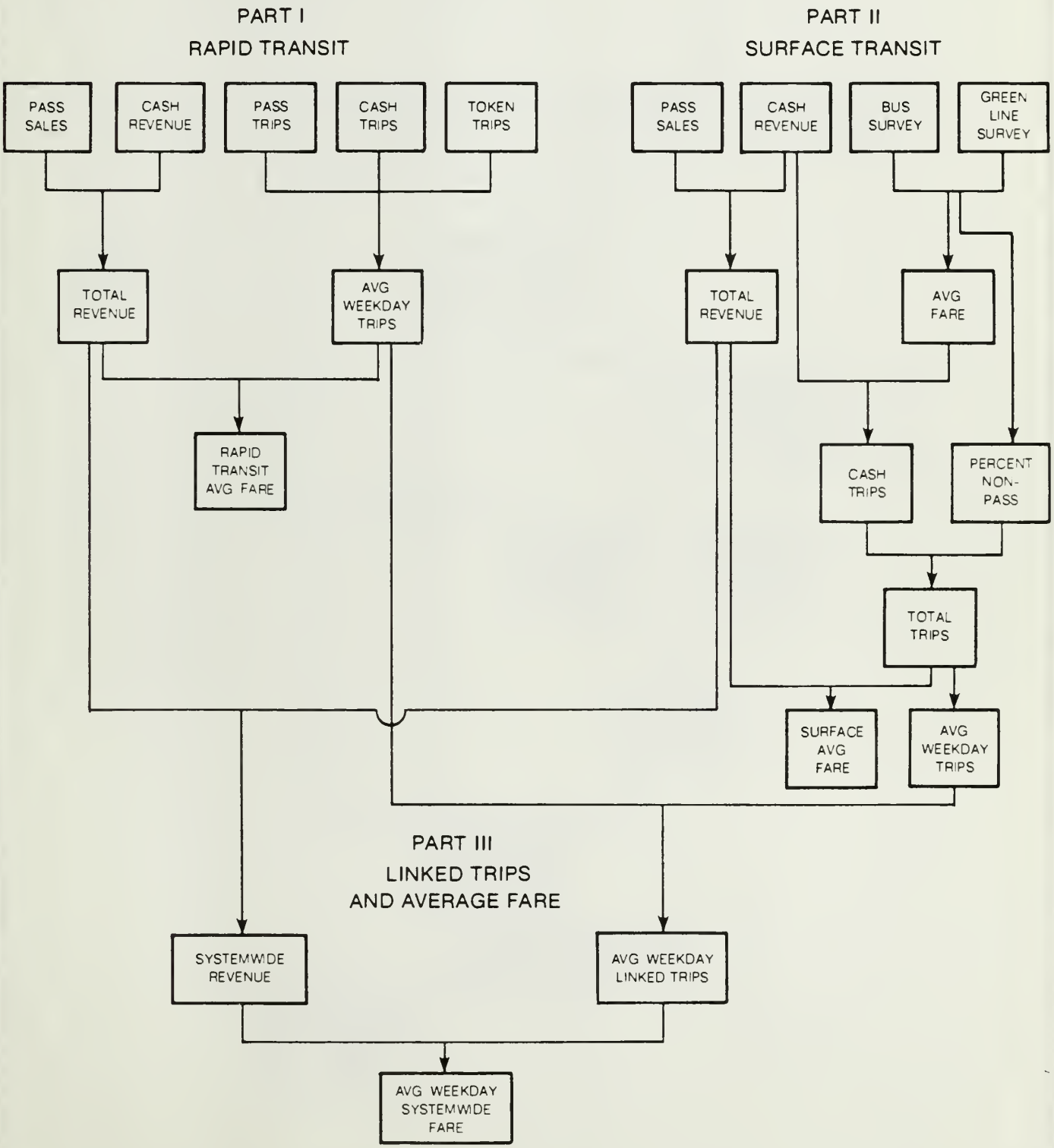
1985 Fare-Mix and Ridership Estimation

		Page
Overview		35
Part I:	Rapid Transit	37
Part I.B:	Rapid-Transit Cash-Gate Trips	39
Part II:	Surface Transit	55
Part III:	Linked Trips and Average Fare	65

*Notes, which follow each part of the diagram, are referred to by the designations at the upper right-hand corner of diagram boxes.

FLOW DIAGRAM OF 1985 FARE-MIX AND RIDERSHIP ESTIMATION

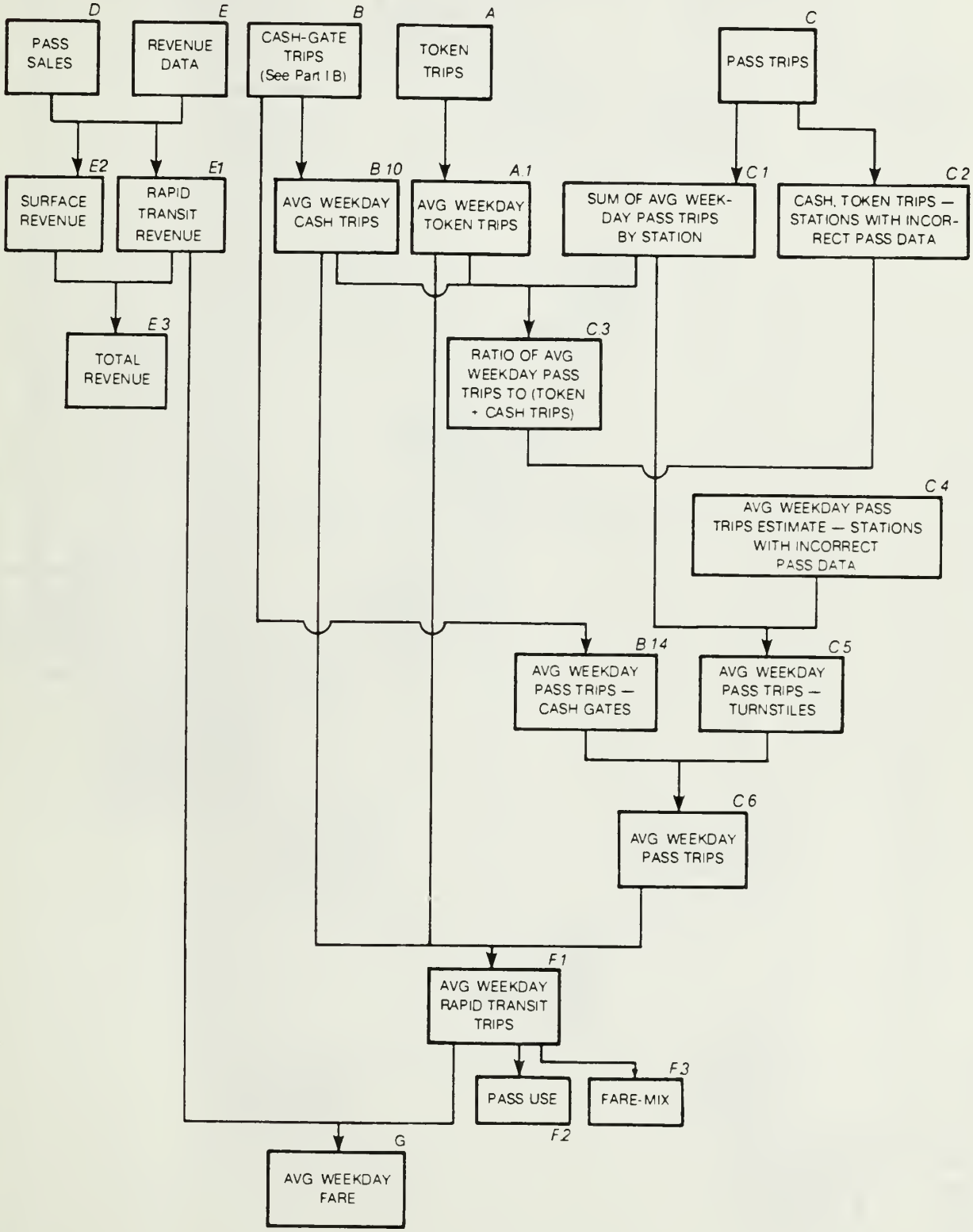
OVERVIEW



FLOW DIAGRAM OF 1985 FARE-MIX AND RIDERSHIP ESTIMATION

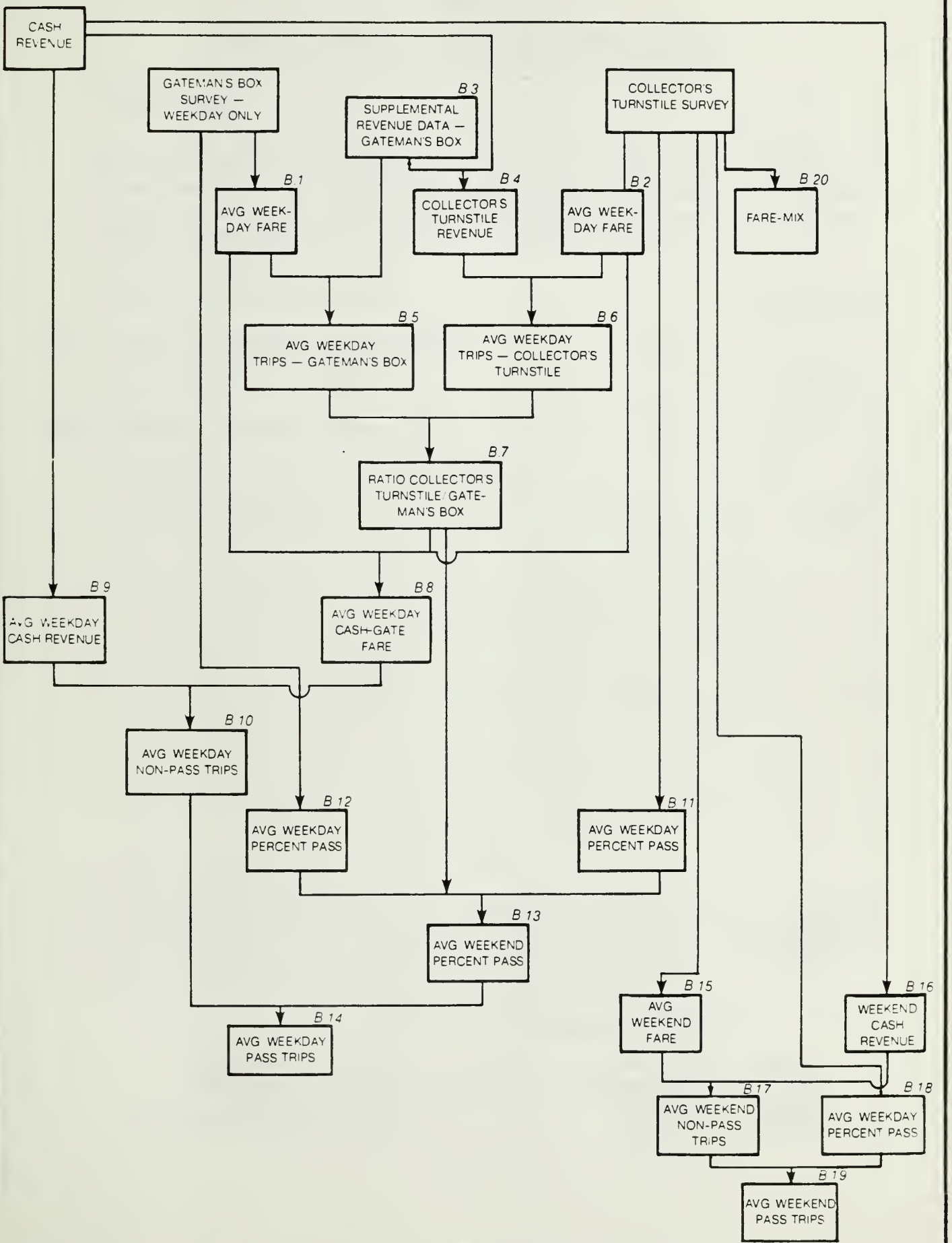
PART I

RAPID TRANSIT



FLOW DIAGRAM OF 1985 FARE-MIX AND RIDERSHIP ESTIMATION

PART I.B
RAPID TRANSIT
CASH-GATE TRIPS



NOTES

Part I - Rapid Transit (Unlinked Trips)

A. TOKEN TRIPS

The number of tokens used in Period 5, 1985, was obtained from the MBTA's Treasurer's office and the RTL210 report. In this analysis, token trips rather than the number of tokens received is used. Since some stations require two or more tokens, the number of tokens received is greater than the actual number of trips.

Token trips in Period 5 = 4,309,674

A.1 Average weekday token trips

4,309,674 ÷ 22.50[1] = 191,541

A.2 Average weekend token trips

Weekend as percent of weekday = 75%

.75 x 191,541 = 143,656

---

[1]22.50 represents the number of weekday equivalent days in period 5, 1985 (October 26-November 22). It is calculated from factors which reflect the type of schedule (as a percent of a weekday schedule) that is in effect on a particular date.

Weekday = 1.00	Period 5, 1985:
Saturday = 0.50	Weekdays = 19.00
Sunday = 0.25	4 Weekends = 3.00
Veteran's Day = 0.50	Holidays = 0.50
	22.50

B. CASH GATE TRIPS

The number of people using cash gates is estimated as a function of the cash received at rapid-transit stations, the weighted average fare of patrons using collectors' turnstiles and gatemen's boxes, and the average pass use.

Daily cash receipts for each station are provided by the RTL210 report. These figures include cash received at gatemen's boxes and collectors' turnstiles combined. Supplemental data on daily cash receipts at gatemen's boxes is provided by the MBTA. By using these data, collectors'-turnstile cash can then be separated from total cash receipts.

Surveys of gatemen's boxes and collectors' turnstiles provide passenger counts and cash collected. From this information, an average weekday fare is derived for both locations and an average weekend fare for collectors' turnstiles. Gatemen's boxes are not surveyed on the weekend because, at most, only two stations have them open. Average pass use is also estimated from survey results.

Average Weekday Fare and Non-Pass Ridership

B.1	Average weekday fare at gatemen's boxes (survey data)	=	31.5¢
B.2	Average weekday fare at collectors' turnstiles (survey data)	=	18.9¢
B.3	Period 5 gatemen's-box revenue (weekdays) (supplemental revenue data)	=	$46,489
B.4	Period 5 collectors'-turnstile revenue (weekdays) (RTL210 cash receipts - gatemen's-box cash)	=	$220,396
B.5	Gatemen's-box average weekday trips (used only for weighting average cash-gate fare)	=	7,568
B.6	Collectors'-turnstile average weekday trips (used only for weighting average cash-gate fare)	=	59,801
B.7	Relative proportion of trips using collectors' turnstiles/gatemen's boxes	=	(.882)/(.118)
B.8	Weighted average weekday fare ($.189)(.882) + ($.315)(.118)	=	20.4¢

B.9	Weekday cash receipts ÷ avg. weekdays Period 5[1] Period 5		
	$266,885 ÷ 19.5	=	$13,686
B.10	Average weekday non-prepaid pass users at cash gates, $13,686 ÷ .204	=	67,088

Average Weekday Pass Use

B.11	Collectors' turnstiles (survey data)	=	32.0%
B.12	Gatemen's boxes (survey data)	=	68.0%
B.13	Weighted average weekday pass use (.882) (.32) + (.118) (.684)	=	36.3%
B.14	Average weekday pass trips (non-pass users) - (proportion non-pass) 67,088 ÷ .637 = 105,319 105,319 - 67,088	=	38,231

Average Weekend Fare and Non-Pass Ridership

B.15	Average weekend fare at collectors' turnstiles	=	23.8¢
B.16	Period 5 cash receipts (weekends) (4 weekends)	=	$63,273
	Average weekend revenue	=	$15,818
B.17	Average weekend ridership, 15,818 ÷ .238	=	66,462

Average Weekend Pass Use

B.18	Average pass use	=	27.9%
B.19	Average weekend pass ridership 66,462 ÷ .721 = 92,180 92,180 - 66,462	=	25,718

---

[1] In 1984, Total Period 5 cash receipts rather than only weekday cash receipts was used. The corresponding figures under B.9 and B.10 for 1985 would be:

Cash receipts, Period 5	$309,212
Number of days	22.5
Average daily cash receipts	13,743
Non-prepaid pass users at cash gates	67,366

B.20 Fare Mix at Collectors' Turnstiles[1]

	Weekday				Weekend[2]			
	1981	1982	1983	1985	1981	1982	1983	1985
Adult Cash	7.5%	12.1%	16.0%	12.1%	51.1%	38.2%	59.0%	21.8%
E&H								
- Free	52.2%	50.5%	-	-	3.0%	-	-	-
- 1/2 Fare	15.0%	21.0%	-	-	31.4%	43.4%	-	-
- Reduced	-	-	64.6%	64.5%	-	-	23.7%	42.0%
Students & Children 1/2 Fare	18.9%	10.9%	15.7%	14.8%	7.1%	9.8%	7.6%	25.5%
Free								
- Authorized	4.9%	4.2%	2.6%	8.5%	6.0%	2.8%	9.0%	9.9%
- Unauthorized	1.5%	1.3%	1.1%	-	1.4%	5.7%	0.7%	0.8%
Average Fare	17.5¢	18.9¢	20.9¢	18.9¢	51.7¢	39.3¢	39.7¢	23.8¢

[1]No survey was conducted in 1984.

[2]Note that the weekend fare-mix and average fare are not consistent with those of previous years. The current mix suggests a shift in use to those paying reduced or no fare. This, however, cannot be substantiated without additional sample data.

C. PASS TRIPS

Passmeter readings for each rapid-transit station are given in the MBTA's RTL210 report. Total values for the period cannot be used as a measure of pass trips because passmeters at a number of stations are disabled, registering no values or incorrect ones. To obtain a more reasonable estimate of pass trips, an average weekday value was calculated for each station, excluding those days with missing or incorrect information. For those stations where no values or too few were recorded to arrive at an average, an estimated value was derived based on pass trips at other stations as a percent of token and cash trips.

In the following calculations average weekday and weekend pass, token, and cash trips were obtained from turnstile data.

	Average Weekday	Average Weekend
C.1 Pass trips		
Stations with usable pass data	84,951	12,127
C.2 Token trips		
Stations without pass data	24,517	18,388
Stations with pass data	167,832	125,068
Total	191,541	143,656
Cash trips		
Stations without pass data	14,088	45,145
Stations with pass data	53,000	21,318
Total	67,088	66,463

Average Weekday Pass Trips

C.3 Average weekday pass trips as a percent of cash and token trips
84,951 ÷ (53,000 + 167,832) = 38.5%

C.4 Estimated missing pass trips (avg. weekday)
(14,088 + 24,517) x .385 = 14,863

C.5 Turnstile average weekday pass trips
14,863 + 84,951 = 99,814

C.6 Total average weekday pass trips
Cash gate (B.14) + Turnstile (C.5)
38,231 + 99,814 = 138,045

Average Weekend Pass Trips

Steps C.3 through C.6 are repeated for estimating weekend pass trips

C.3	12,127 ÷ (21,318 + 125,068)	=	8.28%
C.4	(45,145 + 18,388) x .0854	=	5,261
C.5	5,261 + 12,127	=	17,388
C.6	25,718 + 17,388	=	43,106

D. PREPAID-PASS SALES

The following table lists pass sales for the month of November and the proportion used on the rapid transit system. See the next page for notes.

Distribution of Passes

Type of Pass[1]	Total Passes		Proportion Used on Surface Transit		Proportion Used on Rapid Transit	
	No.	Revenue	No.[2]	Revenue	No.[2]	Revenue
A $18	16,893	$ 304,074	16,893 (100.0%)	$ 304,074 (100.0%)	-	-
B $22	45,585	1,002,870	6,154 (13.5%)	135,388 (13.5%)	39,431 (86.5%)	$ 867,483 (86.5%)
C $36	30,749	1,106,964	27,982 (91.0%) 1,384 (4.5%)	453,855 (41.0%) 49,813 (4.5%)	27,982 (91.0%) 1,384 (4.5%)	553,482 (50.0%) 49,813 (4.5%)
D $40	4,877	195,080	2,526 (51.8%) 1,083 (22.2%)	103,392 (53.0%)	2,526 (51.8%) 1,268 (26.0%)	91,688 (47.0%)
E $48	5,210	250,080	3,751 (72.0%) 1,459 (28.0%)	162,552 (65.0%)	3,751 (72.0%)	87,528 (35.0%)
F $56	1,468	82,208	1,468 (100.0%)	41,104 (50.0%)	1,468 (100.0%)	41,104 (50.0%)
	104,782	$2,941,276	62,700	$1,250,178	76,542	$1,691,098

	Number	Revenue
Commutation Tickets (Express Bus & Green Line Only)	1,853	$25,956

Student Passes	Bus		Rapid Transit	
	Number	Revenue	Number	Revenue
Bus Only	7,472	$74,720		
Bus & Rapid Transit	4,240	21,200	4,240	$21,200
	11,712	$95,920	4,240	$21,200

Notes to table from preceding page.

[1]Table showing the cost of pass, the maximum value per trip and the mode(s) are as follows:

A - $0.50 Surface Vehicle Only

B - $0.60 Rapid Transit (including Mattapan High-speed Line) and Streetcar

C - $1.00 Rapid Transit, Streetcar, Bus, and Express Bus

D - $1.25 Rapid Transit, Streetcar, Bus, Express Bus, and Zone 1 Commuter Rail

E - $1.50 Rapid Transit, Streetcar, Bus, Express Bus, and Zone 2 Commuter Rail

F - $1.75 All MBTA Services and Zone 3 Commuter Rail

[2]For some types of passes, two entries are given for the number of passes used on each portion of the transit system. An example is the entries for pass-type C under surface transit. The top number, 27,982, refers to the number of passes used on both surface and rapid transit, and the bottom number, 1,384, refers to the number of passes used solely on surface transit.

Passes are purchased on a monthly basis, so revenue and passes must be converted to equivalent period figures. The conversion method is the same as the one that was used in previous years. That is, the portion of October days contained in Period 5 of the fiscal year was applied to sales for that month and the portion of November days not included in Period 5 was applied to November sales. November sales were adjusted by these figures to arrive at Period 5 values. In previous reports student passes and revenue were simply discounted by 8 percent, because they did not vary significantly between the two months. The 8-percent discount represented the ratio between the number of days in November and in Period 5 of that fiscal year. In this year's analysis, however, the above conversion method was used for student passes and revenue because there were considerable differences between the two months.

October weekday equivalent = 25.50
November weekday equivalent = 23.25

Portion of October in Period 5
October 26-31 = 4.75
4.75 ÷ 25.50 = 18.6%

Portion of November not in Period 5
November 23-30 = 5.50
5.50 ÷ 23.25 = 23.7%

Rapid Transit

Prepaid Pass Revenue

October revenue adjustment
$1,589,132 x .186 = $295,579

November revenue adjustment
$1,691,098 x .237 = $400,790

Period 5 pass revenue
$1,691,098 - $400,790 + $295,579 = $1,585,887

Student Pass Revenue

October revenue adjustment
$21,880 x .186 = $4,070

November revenue adjustment
$21,200 x .237 = $5,024

Period 5 student pass revenue
$21,200 - $5,024 + $4,070 = $20,246

Number of Passes

October proportion 4.75 ÷ 22.50 = .211
November proportion 17.75 ÷ 22.50 = .789

Period 5 prepaid passes
(76,542 x .789) + (72,007 x .211) = 75,585

Student passes
(4,240 x .789) + (4,376 x .211) = 4,268

Total Period 5 passes = 79,853

Surface Transit

Prepaid Pass Revenue

October revenue adjustment
1,174,798 x .186 = 218,512

November revenue adjustment
1,250,178 x .237 = 296,292

Period 5 pass revenue
1,250,178 - 296,292 + 218,512 = $1,172,398

Student Pass Revenue

October revenue adjustment
$99,000 x .186 = $18,414

November revenue adjustment
$95,920 x .237 = $22,733

Period 5 student pass revenue
$95,920 - $22,733 + $18,414 = $91,601

Total Period 5 surface pass revenue = $1,263,999

Number of Passes

October proportion 4.75 ÷ 22.50 = .211
November proportion 17.75 ÷ 22.50 = .789

Period-5 passes
(62,700 x .789) + (59,074 x .211) = 61,935

Student passes
(11,712 x .789) + (12,088 x .211) = 11,792

Total Period-5 passes = 73,727

E. REVENUE

The revenue for Period 5, 1985, distributed to rapid transit and surface transit is as follows:

E.1 Rapid Transit Revenue

Revenue from tokens used		$2,625,562/period
Cash-gate revenue		309,212/period
Pass revenue	$1,691,098/November $1,589,132/October	1,585,887/period[1]
Student pass	$21,200/November $21,880/October	20,246/period
Total Transit Revenue		$4,540,907/period

E.2 Surface Transit Revenue

Fare box revenue		$2,619,154/period
Non-fare-box revenue		
Prepaid pass	$1,259,178/November $1,174,798/October	1,172,398/period
Student pass	$95,920/November $99,000/October	91,601/period
Total Surface Revenue		$3,883,153/period

E.3 Total Period 5 Revenue $8,424,060/period

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[1]For the adjustment of monthly pass revenue to an accounting period basis, see section D of these flow-diagram notes.

F. RAPID-TRANSIT TRIPS

F.1 Unlinked Rapid-Transit Trips

	1983	1985
Average Weekday		
Token trips (A.1)	157,143	191,541
Prepaid pass (C.6)	119,992	138,045
Non-pass cash gate (B.10)	70,379	67,088
Total	347,514	396,674
Average Weekend		
Token trips (A.2)	117,857	143,656
Prepaid pass (C.6)	69,703	43,106
Non-pass cash gate (B.17)	46,381	66,463
Total	233,941	253,225

F.2 Uses per Prepaid Pass

Pass Trips per Period

Avg. Weekday Pass Trips (C.6)	x	Weekday Factor	+	Avg. Weekend Pass Trips (C.6)	x	Weekend Factor
(138,045	x	19.50)	+	(43,106	x	4) = 2,865,302

Pass Trips per Period	÷	Passes Used on Rapid Transit (D)	
2,865,302	÷	79,853	= 35.88 uses per period
35.88	÷	22.50	= 1.6 uses per day

F.3 The fare mixes for unlinked rapid-transit trips representing a composite value for an average weekday and an average weekend are as follows:

Fare Mix	Weekday				Weekend			
	1981	1982	1983	1985[1]	1981	1982	1983	1985
Adult								
- Cash	48.5%	49.9%	48.6%	50.3%	65.4%	58.2%	62.1%	62.4%
- Pass	29.2	32.3	32.3	34.8	26.2	28.9	29.8	17.1
E&H								
- Free	11.1	8.9	-	-	0.5	-	-	-
- 1/2 Fare	3.8	3.2	-	-	5.4	9.0	-	-
- Reduced	-	-	13.5	11.0	-	-	4.7	11.0
Students & Children								
- Pass	-	2.9	3.3	-	-	-	-	-
- 1/2 Fare	5.8	1.9	1.6	2.5	1.2	2.0	1.5	6.7
Free								
- Authorized	1.2	0.8	0.5	1.0	1.0	0.6	1.8	2.6
- Unauthorized	0.4	0.2	0.2	-	0.2	1.2	0.1	0.2
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[1]No rapid-transit survey was conducted in 1984.

G. AVERAGE FARE FOR UNLINKED RAPID-TRANSIT TRIPS

Rapid-Transit Revenue ÷ Number of Rapid-Transit Trips = Average Fare

$$\text{Period 5 Revenue} \div \left[\left(\begin{matrix}\text{Average}\\ \text{Weekday}\\ \text{Trips}\end{matrix}\right)\left(\begin{matrix}\text{Week-}\\ \text{day}\\ \text{Factor}\end{matrix}\right) + \left(\begin{matrix}\text{Average}\\ \text{Weekend}\\ \text{Trips}\end{matrix}\right)\left(\begin{matrix}\text{Week-}\\ \text{end}\\ \text{Factor}\end{matrix}\right)\right] =$$

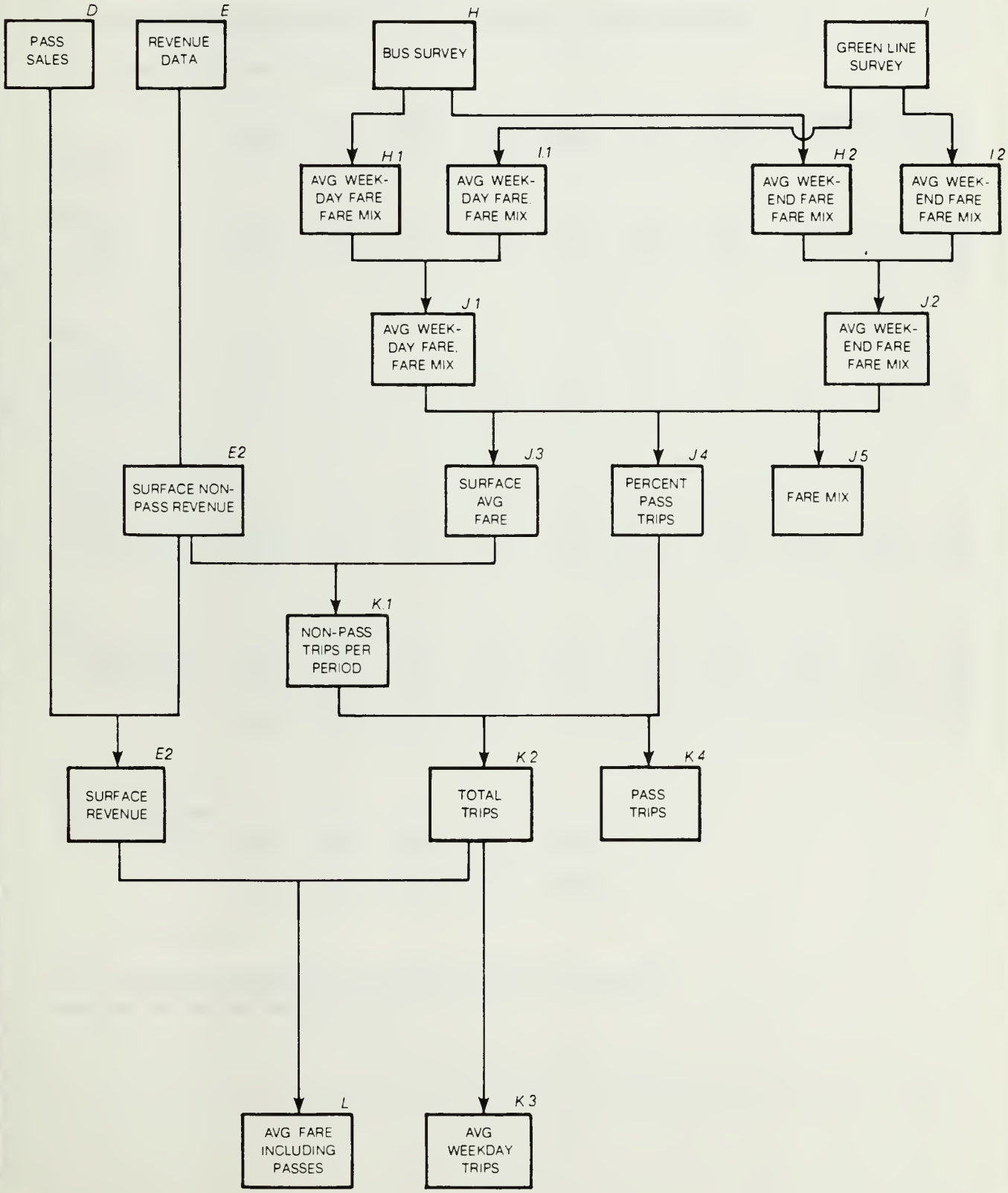
$$4{,}540{,}907 \div \left[(396{,}674)(19.50) + (253{,}225)(4)\right] =$$

$$4{,}540{,}907 \div \left[7{,}735{,}143 + 1{,}012{,}900\right] = 51.9¢$$

FLOW DIAGRAM OF 1985 FARE-MIX AND RIDERSHIP ESTIMATION

PART II

SURFACE TRANSIT



NOTES

Part II - Surface Transit/Unlinked Trips

H. BUS SURVEY

The survey conducted on the bus lines produced the following results:

H.1 Average Weekday Fare, Fare Mix

	Bus					Trackless Trolley				
	1981	1982	1983	1984	1985	1981	1982	1983	1984	1985
Fare Mix										
Adult										
- Cash	38.6%	35.4%	36.7%	35.9%	34.3%	43.1%	31.3%	37.9%	38.1%	50.0%
- Pass	32.1	33.9	33.1	25.9	31.7	43.0	45.1	36.5	36.9	22.4
E&H										
- Free	7.4	11.9	-	-	-	5.7	12.5	-	-	-
- 1/2 Fare	5.2	4.1	-	-	-	5.4	0.7	-	-	-
- Reduced	-	-	12.0	12.5	14.4	-	-	10.5	16.9	19.2
Students & Children										
- Pass	3.2	4.1	4.5	4.7	4.3	-	5.0	3.4	0.7	1.9
- 1/2 Fare	12.4	9.6	13.1	10.1	12.9	2.4	5.4	10.2	6.3	5.8
Free										
- Authorized	0.6	1.0	0.5	0.8	2.2	0.4	0.0	1.5	1.0	0.7
- Unauthorized	0.5	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Average fare[1] for Bus & Trackless Trolley Combined	1981	1982	1983	1984	1985
	40.3¢	36.3¢	39.7¢	40.1¢	38.3¢

[1]The average fare represents the weighted average by bus garage and does not include pass revenue.

H.2 Average Weekend Fare, Fare Mix[1]

Fare Mix	Bus				
	1981	1982	1983	1984	1985
Adult					
- Cash	46.5%	39.6%	46.4%	44.2%	38.5%
- Pass	28.4	37.0	30.4	31.0	25.7
E&H					
- Free	0.8	-	-	-	-
- 1/2 Fare	11.7	14.6	-	-	-
- Reduced	-	-	15.2	17.3	24.2
Students & Children					
- Pass	0.3	-	-	-	-
- 1/2 Fare	9.2	7.1	5.7	5.6	6.9
Free					
- Authorized	2.2	1.5	2.1	1.6	3.5
- Unauthorized	0.9	0.2	0.2	0.3	1.2
	100.0%	100.0%	100.0%	100.0%	100.0%
Average Fare	41.5¢	41.9¢	39.0¢	43.2¢	40.6¢

[1]Trackless trolleys began operating on Saturdays in September 1985. However, no trackless-trolley trips were selected in the random sample of the weekends.

I. GREEN LINE SURVEY

The survey conducted on the surface portion of the Green Line resulted in the following fare mix and average fare.

	I.1 Weekday					I.2 Weekend				
Fare Mix	1981	1982	1983	1984	1985	1981	1982	1983	1984	1985
Adult										
-Cash	38.4%	29.6%	31.1%	31.9%	34.5%	44.3%	41.6%	35.6%	41.2%	40.2%
-Pass	25.3	27.4	28.0	27.7	30.9	22.9	21.1	23.0	25.4	27.1
E&H										
-Free	5.9	3.6	-	-	-	0.4	-	-	-	-
-1/2 Fare	1.6	0.9	-	-	-	4.4	4.4	-	-	-
-Reduced	-	-	7.3	4.1	5.8	-	-	5.8	5.3	6.4
Students & Children										
-Pass	0.2	0.1	0.8	0.8	0.7	-	-	-	-	-
-1/2 Fare	1.1	1.5	1.5	1.2	1.7	1.8	1.3	1.3	1.9	2.0
Free										
-Authorized	27.0	36.9	31.2	34.3	26.4	26.2	31.4	34.3	26.0	24.3
-Unauthorized	0.0	-	0.1	0.0	0.0	-	0.2	0.1	0.2	0.0
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Average Fare[1]	41.7¢	33.7¢	37.4¢	40.6¢	40.3¢	48.2¢	45.7¢	40.4¢	49.0¢	46.8¢

[1]The average fare represents the weighted average of the four components of the surface Green Line and does not include pass revenue.

J. AVERAGE FARE AND FARE MIX (SURFACE TRANSIT)

Ridership estimates are derived for the bus and trackless trolley systems and surface Green Line using average fares from the six sampling periods and average revenue from Period 5, FY1985. These ridership figures are then used in weighting the average fare and fare mix to arrive at composite estimates. The calculations for average fare and adult pass use are given below.

Weekday	Revenue	÷	Avg. Fare	=	Ridership Estimate	Proportion of Total Ridership
Bus	$81,032	÷	$.368	=	220,196	.744
Trackless Trolley	$ 3,395	÷	$.349	=	9,728	.033
Green Line	$26,595	÷	$.403	=	65,993	.223
Weekend						
Bus	$70,769	÷	$.406	=	174,308	.678
Green Line	$38,769	÷	$.468	=	82,840	.322

J.1 Average Weekday Fare and Percentage Pass Use

Average Fare Ridership Proportion for Bus, Trackless Trolley and Green Line: ($.368)(.744) + ($.349)(.033) + (.403)(.223) = 37.5¢

Proportion of Pass use for Bus, Trackless Trolley and Green Line:
(.311)(.744) + (.224)(.033) + (.309)(.223) = 30.8%

J.2 Average Weekend Fare and Percentage Pass Use

Average Fare	($.406)(.678) + ($.468)(.322) = 42.6¢
Pass	(.257)(.678) + (.271)(.322) = 26.2%

Combining the weekday and weekend averages yields a composite average fare (J.3), pass use (J.4) and fare mix (J.5).

J.3 Average Fare

($.375)(.8696)[1] + ($.426)(.1304)[2] = 38.2¢

J.4 Percent Pass

(.308)(.8696) + (.262)(.1304)	= 30.2%
Weighted average of student pass use	= 3.4%
Total	= 33.6%

[1]Percent of equivalent days weekday.
[2]Percent of equivalent days weekend.

J.5 Fare Mix

	Weekday and Weekend				
	1981	1982	1983	1984	1985
Adult					
- Cash	39.6%	34.9%	36.4%	36.6%	35.4%
- Pass	30.7	32.6	31.4	33.2	30.2
E&H					
- Free	6.3	8.9	-	-	-
- 1/2 Fare	5.3	4.3	-	-	-
- Reduced	-	-	11.0	11.1	13.0
Students & Children					
- Pass	2.3	2.9	3.1	2.7	3.4
- 1/2 Fare	9.9	7.4	9.3	7.4	10.0
Free					
- Authorized[1]	5.4	9.0	8.7	9.0	7.8
- Unauthorized	0.5	-	-	-	0.2
	100.0%	100.0%	100.0%	100.0%	100.0%
Average Fare[2]	41.1¢	36.7¢	39.1¢	40.9¢	38.2¢

[1]Includes passengers riding free in the outbound direction on the surface Green Line.

[2]Does not include pass revenue.

K. SURFACE TRIPS

The number of unlinked average weekday surface trips was estimated using the composite average fare and the average surface revenue for the six survey periods.

Surface non-pass revenue (E.2)
less commutation-ticket revenue

$2,619,154 - 26,596 = $2,592,558

K.1 Non-pass Trips per Period

Revenue ÷ Non-pass avg. fare = 2,592,558 ÷ .382 = 6,786,801

Plus ticket trips

18,530 ÷ 1.08 = 17,157 per period
6,786,801 + 17,157 = 6,803,958

K.2 Total Trips per Period

Non-pass trips ÷ Fraction of total that are non-pass

6,803,958 ÷ .664 = 10,246,924

K.3 Average Weekday Trips

Total trips ÷ Factored avg. weekdays

10,246,924 ÷ 22.5 = 455,419

K.4 Uses per Prepaid Pass

Pass trips ÷ Passes used on surface per period

(10,246,924 - 6,803,958) ÷ 73,727 = 46.7 uses per period

46.7 ÷ 22.50 = 2.1 uses per day

L. AVERAGE FARE FOR UNLINKED SURFACE TRIPS

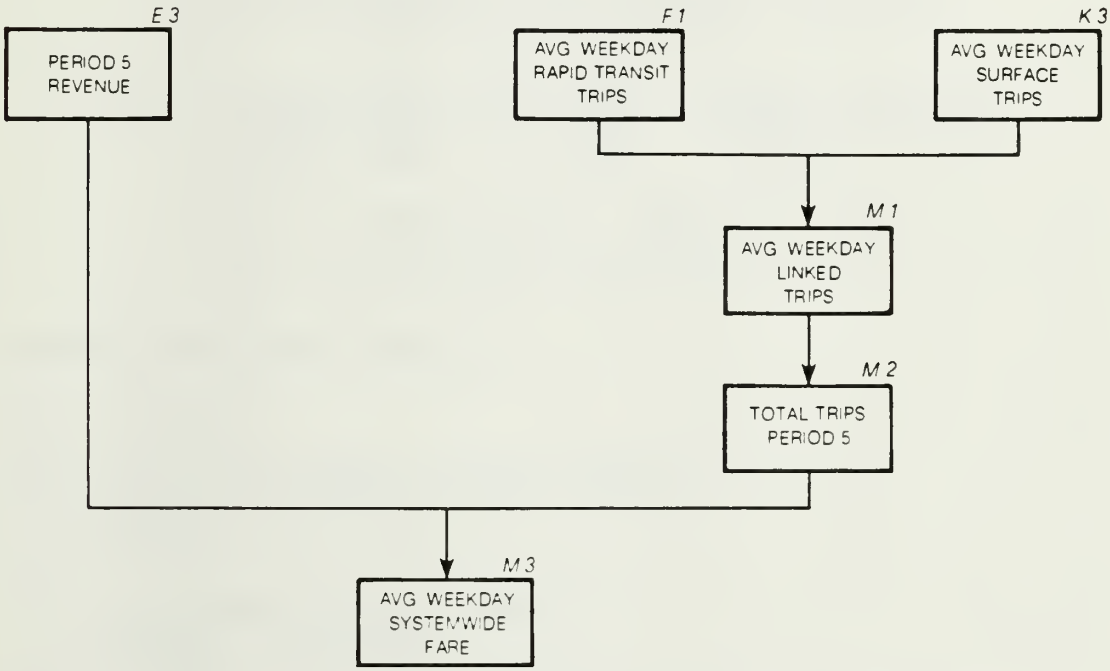
Total surface revenue (E.2) ÷ Total surface trips (K.2)

3,883,153 - 10,246,924 = 37.9¢

FLOW DIAGRAM OF 1985 FARE-MIX AND RIDERSHIP ESTIMATION

PART III

LINKED TRIPS AND AVERAGE FARE



NOTES

Part III - Linked Trips and Average Fare

M. Average weekday linked trips and the corresponding average fare were estimated using the following procedure:

Unlinked rapid transit trips = 396,674
Unlinked surface trips = 455,419

Rapid transit only = X (29%) (Percentages from
Combination = Y (40%) 1978 Systemwide
Surface only = Z (31%) Survey)

$X + Y = 396,539$ ($X = 396,674 - Y$)
$Z + Y = 455,419$ ($Z = 455,419 - Y$)
$Y - (X + Y + Z) = .40$

Solving the third equation:

$Y = 243,455$

X = (unlinked rapid transit trips) - Y
= 396,674 - 243,455
= 153,219

Z = (unlinked surface trips) - Y
= 455,419 - 243,455
= 211,964

15% of these trips are surface-to-surface transfers

Z' = 211,964 x .85
= 180,169

M.1 X + Y + Z' = total linked trips/weekday
153,219 + 180,169 + 243,455 = 576,843

M.2 Weekday linked trips x period factor = linked trips/period
576,843 x 22.5 = 12,978,968

M.3 Average fare
$8,424,060 ÷ 12,978,968 = 64.9¢

Total unlinked trips per period
455,419 + 396,674 = 852,093

APPENDIX 2

Survey Samples and Schedules

TABLE A-2a

TRIPS[1] SAMPLED PER GARAGE
1985

Garage	Total Average Weekday Trips	Trips Sampled
Cabot/Albany	4070	31
Arborway	2194	23
Salem	1068	10
Somerville/Charlestown	3150	30
Lynn	1260	16
Quincy	1243	14
Bennett*	571	6
	13,556	130

Garage	Total Average Weekend Trips	Trips Sampled
Cabot/Albany	3756	8
Arborway	2028	6
Salem	0	0
Somerville/Charlestown	4621	15
Lynn	1154	4
Quincy	1131	2
	12,960	35

[1]One-way trips
*Trackless trolley

TABLE A-2b

SURFACE-GREEN-LINE SURVEY SCHEDULE
1985

Branch	Valid Trips	Trips Required	Date(s)
Weekday			
Boston College	42	10	11/5, 11/12-11/15
Cleveland Circle	24	8	11/5, 11/12-11/15
Riverside	30	9	11/5, 11/12-11/15
Arborway	24	7	11/5, 11/12-11/15
Weekend			
Boston College	24	12	11/3, 11/16-11/17, 11/23
Cleveland Circle	22	9	11/3, 11/16-11/17, 11/23
Riverside	30	11	11/3, 11/16-11/17, 11/23
Arborway	30	9	11/3, 11/16-11/17, 11/23

TABLE A-2c, p.1

BUS AND TRACKLESS-TROLLEY SURVEY SCHEDULE

1985

Day of Week	District	Route Number	Date of Count
Weekday	Cabot/Albany	16	6/10
		17,23,44	6/11
		1	6/13
		57,68	6/14
		7,15,22,66	8/7
		43	8/26
		11	8/28
		68	8/29
		43	9/30
		23	10/1
		22,53,300	10/2
		7,15,310,304	11/25
		17,44,304	12/3
		1,7,11,22,65	12/17
	Arborway	32	6/10
		32,34	6/13
		32	6/14
		36	8/7
		24,32,36,38	8/8
		38,41	8/26
		29,37	9/30
		34,37	10/2
		36	11/25
		21,30,36,42	12/4
	Salem	136	6/11
		108	6/3
		97	6/14
		325	8/5
		95	8/9
		94	8/25
		95	9/30
		108,325	10/1
		136	12/5
		134	12/18
	Somerville	77	6/11,6/13
		77	8/5
		63,74,75	8/6
		74	8/8
		77	8/27
		77,63	8/29
		69	8/30

TABLE A-2c, p.2

BUS AND TRACKLESS-TROLLEY SURVEY SCHEDULE

1985 (Continued)

Day of Week	District	Route Number	Date of Count
	Somerville (Cont.)	80	10/2
		83	10/6
		85	11/12
		85,88	11/14
		87	12/2
		86	12/17
	Charlestown	112,134	6/12
		89	8/6
		104	8/9
		92,93,101	8/29
		93	10/1
		89,110	11/14
		110	12/5
	Lynn	120,437	6/10
		429,442	8/9
		116,119,120,429	8/27
		450	10/3
		430	12/3
		441,442	12/5
		426	12/17
		441,455	12/18
	Quincy	215,228	8/28
		215,240	10/4
		215	11/26
		230	12/3
		210	12/9
		211,214,216,217,220	12/16
		216	12/18
	Bennett[1]	71	6/12
		73	6/14
		71	8/6
		71	10/2
		73	10/4
		73	12/3

[1]Trackless Trolley

TABLE A-2c, p.3

BUS AND TRACKLESS-TROLLEY SURVEY SCHEDULE

1985 (Continued)

Day of Week	District	Route Number	Date of Count
Saturday	Cabot/Albany	23,58,66	6/8
		11	8/10
		16	10/5
	Arborway	34,50,51	8/10
		35	10/5
		34,50	11/2
	Somerville	70	6/8
		69,77	8/10
		63,69	11/2
	Charlestown	93,96	10/5
		89	11/2
	Lynn	450	11/2
	Quincy	237	8/10
		230	10/5

TABLE A-2c, p.5

BUS AND TRACKLESS-TROLLEY SURVEY SCHEDULE

1985 (Continued)

Day of Week	District	Route Number	Date of Count
Sunday	Cabot/Albany	1	6/9
		49	8/21
		11	11/24
	Somerville	73	11/3
	Charlestown	94	6/9
		93	8/1
		106	11/3
	Lynn	455	8/11
		400	11/24

TABLE A-2d

RAPID-TRANSIT COUNT
COLLECTORS' TURNSTILE SAMPLE
1985

WEEKDAY (12)[1]

6 AM - 10 AM (6)
- Lechmere
- Wonderland
- Orient Heights
- Malden
- Shawmut
- Central Square

11 AM - 2 PM (1
- North Station

3 PM - 6 PM (5)
- Government Center
- Maverick
- Sullivan
- Park Under
- Haymarket - Green

WEEKEND (22)

Saturday (10)	Sunday (12)
6 AM - 10 PM (3)	6 AM - 10 AM (4)
Sullivan	Egleston
Wollaston	Braintree
State - Blue	Airport
	Canal - North Station
10 AM - 2 PM (4)	10 AM - 2 PM (4)
Malden	Oak Grove
Airport	Dudley
Auditorium	Arlington
Arlington	Government Center
2 PM - 6 PM (3)	2 PM - 6 PM (4)
Harvard	North Quincy
North Quincy	Copley
Northampton	Washington - Orange
	Haymarket - Green

[1]Numbers in parentheses indicate number of stations at which collectors' turnstiles were to be sampled during each time period.

TABLE A-2e

RAPID-TRANSIT STATIONS
GATEMEN ASSIGNMENTS
1985

Stations	Gateman Hours	Total Hours
Dudley	7:00 AM - 10:00 AM	3
Porter Square	6:30 AM - 9:30 AM	3
Forest Hills	6:30 AM - 9:30 AM	3
Harvard	7:00 AM - 12:00 PM	5
	3:00 PM - 4:30 PM	1.5
Fields Corner	6:30 AM - 9:30 AM	3
	12:30 PM - 3:30 PM	3
Ashmont	6:30 AM - 9:30 AM	3
	12:30 PM - 3:30 PM	3

APPENDIX 3

Survey Forms

FARE MIX AND RIDERSHIP CHARACTERISTICS
GREEN LINE SURVEY FORM

NAME					DATE		1	2	3	4	5
CAR HOUSE				6	VEHICLE #		7	8	9	10	
ROUTE #			11	12	13	DIRECTION	O INBOUND O OUTBOUND				14
START TIME	A.M. P.M.	15	16	17	18						

PASSENGER COUNTING

ADULT	CASH FARE		19	20	21
	PASS		22	23	24
E & H	REDUCED FARE		25	26	27
STUDENT & CHILDREN	1/2 FARE		28	29	30
	PASS		31	32	33
OTHER FREE	AUTHORIZED		34	35	36
	NON AUTHORIZED		37	38	39

PORTAL LOAD COUNT

# ONBOARD AFTER LAST ABOVE GROUND STOP INBOUND		40	41	42	# ONBOARD AFTER LAST BELOW GROUND STOP OUTBOUND		43	44	45

FARE BOX READING

CASH	BEGIN:	46	47	48	49	50	CASH	END:	51	52	53	54	55
PENNY	BEGIN:	56	57	58	59	60	PENNY	END:	61	62	63	64	65
TOKEN	BEGIN:	66	67	68	69	70	TOKEN	END:	71	72	73	74	75
$ BILLS RECEIVED DURING TRIP											76	77	78

BUS SURVEY FORM

NAME		DATE	
GARAGE		BUS #	
RUN #		ROUTE #	
DIRECTION	O INBOUND O OUTBOUND	SCHEDULED START TIME	O AM O PM
ACTUAL START TIME	O AM O PM	ACTUAL ARRIV. TIME	O AM O PM

PASSENGER COUNTING

ADULT	CASH FARE	
	PASS	
E & H	REDUCED FARE	
STUDENT & CHILDREN	HALF FARE	
	PASS	
OTHER FREE	AUTHORIZED	
	NON AUTHORIZED	

FARE BOX READING

CASH	BEGIN:	CASH	END:	
PENNY	BEGIN:	PENNY	END:	
TOKEN	BEGIN:	TOKEN	END:	
$ BILLS				

FARE MIX AND RIDERSHIP CHARACTERISTICS
RAPID TRANSIT STATION SURVEY FORM (COLLECTOR'S TURNSTYLE)

NAME		STATION	
DATE		ENTRANCE	
DAY OF WEEK		START TIME	O AM O PM

PASSENGER COUNTING

TIME PERIOD					
E & H	REDUCED FARE				
STUDENTS & CHILDREN	HALF FARE				
	PASS				
ADULTS	CASH FARE				
	PASS				
OTHER FREE	AUTHORIZED				
	NON AUTHORIZED				

PASSENGER READING

READING	BEGIN:	READING	END:

FARE BOX AND METER READINGS

CASH	BEGIN:	CASH	END:
PENNY	BEGIN:	PENNY	END:
TOKEN	BEGIN:	TOKEN	END:
TURNSTYLE METER	BEGIN:	TURNSTYLE METER	END:

Fare Mix and Ridership Characteristics

Rapid Transit Station Survey Form (Gate w/ Attendants)

Name		Station	
Date		Entrance	
Day of the Week		Start Time	○ A.M. ○ P.M.

Passenger Counting

Time Period	Prepaid Pass	Full Fare	Other	Total

Passenger Reading if Any

Reading	Begin:	End:

Fare Box Reading

Cash	Begin:	End:
Penny	Begin:	End:
Token	Begin:	End:

Remarks

APPENDIX 4

Section 15 Results

CTPS

State Transportation Building
10 Park Plaza, Suite 2150
Boston, MA 02116-3968
(617) 973-7100

CENTRAL
TRANSPORTATION
PLANNING
STAFF

MEMORANDUM

TO: Anne Herzenberg, MBTA

May 5, 1986

FROM: Erik Holst-Roness

RE: Section 15 Data

Note: This memo supersedes those of March 20th and April 7th.

1.0 Introduction

The reporting of passenger trips and passenger miles is required as part of the annual Section 15 report to UMTA. In this memo, the 1985 statistics for the MBTA Bus and Trackless Trolley systems are presented along with the methods used to calculate them.

The memo is divided into three main sections. The first discusses the method and the calculations involved in the estimation process and presents the results. The second section deals with the actual survey data, discussing the extent and types of errors that were present. The final part shows the calculations involved in establishing that the data used in the estimation process do meet UMTA's requirements of confidence and precision.

2.0 Method and Calculations

The use of a revenue-based sampling method is more efficient than previous methods used for Section 15 data.[1] This method enables the total required sample size to be reduced considerably, while retaining specified confidence and precision levels (95 percent and ± 10 percent, respectively).

Sample results were loaded into a computer program designed specifically for the analysis of Section 15 data.[2] The output provides a summary of the data contained in the sample. This summary is shown in Table 1.

---

[1] UMTA Circular "Revenue Based Sampling Procedures for Obtaining Fixed Route Bus Operating Data Required Under the Section 15 Reporting System," December 19, 1983.

[2] Program to accept Section 15 survey data and present summaries, Dan Beagan, CTPS.

The items of data contained in Table 1 can then be used to generate systemwide results. The results required for Section 15 are calculated as follows:

$$\text{A) ESTIMATED UNLINKED PASSENGER TRIPS}^3 = \frac{\text{Total Annual System Farebox Revenue}}{\text{Cumulative Average Farebox Revenue per Passenger}}$$

$$\text{B) ESTIMATED UNLINKED PASSENGER MILES}^3 = \frac{\text{Total Annual System Farebox Revenue}}{\text{Cumulative Average Farebox Revenue Per Passenger Mile}}$$

Table 1

SUMMARY TABLE, OUTPUT OF SECTION 15 SURVEY DATA

1.1 Accumulated from Bus Survey Records

	Weekdays	Saturday	Sunday	Total
Passengers Boarded	4164	621	286	5071
Bus Trip Distance	734	122	60	916
Passenger Miles	9980	1388	691	12060
Trips in Sample	146	24	13	183
Total Revenue*	1012.47	165.65	61.20	1239.32

1.2 Sample Averages

	Weekdays	Saturday	Sunday	Total
Passengers Per Trip	28.52	25.88	22.00	27.71
Passenger Miles Per Trip	68.36	57.85	53.15	65.90
Revenue Per Trip	6.9347	6.9	4.71	6.7722
Revenue Per Passenger	0.2431	0.27	0.21	0.2442
Revenue Per Pass. Mile*	0.1014	0.12	0.09	0.1028

---

[3]Passenger revenues collected through passes are excluded. Source: the previously-cited UMTA Circular of December 19, 1983.

*Definitions in Appendix Table A2

The worksheet by which the results were obtained, shown in Table 2, is similar to that provided in the associated UMTA circular on revenue-based sampling methods.[4]

Table 2

WORKSHEET FOR CALCULATING ANNUAL BUS PASSENGER TRIPS AND PASSENGER MILES (REVENUE-BASED METHOD)

Year: 1985 Sampling Period:	Weekday	Saturday	Sunday	Total
A) Farebox Revenue ($)	_____	_____	_____	$24,815,317
B) Cumulative Revenue per Passenger Trip ($/pass) for Period	0.243	0.27	0.21	0.244
C) Cumulative Revenue per Passenger-Mile ($/pass-mi) for Period	0.101	0.12	0.09	0.103
D) Estimated System Passenger Trips (pass) ((D) = (A) ÷ (B))	_____	_____	_____	101,618,825
E) Estimated System Passenger-Miles (pass-mi) ((E) = (A) ÷ (C))	_____	_____	_____	241,394,134

[4]The UMTA Circular of December 19, 1983, is associated with UMTA Circular 2710.1 of February 22, 1978.

2.1 Bus Results

The required results for Section 15 are presented in Table 3.

Table 3

REQUIRED SECTION 15 PASSENGER TRIPS AND PASSENGER MILES

1) Estimated Unlinked Bus Passenger Trips = 101,618,825
2) Estimated Unlinked Bus Passenger Miles = 241,394,134

At the time of writing, only total farebox revenue (see Table 2, A) was available. Table 3, therefore, only shows the total estimated unlinked passenger trips and miles. Weekday, Saturday and Sunday estimates can be obtained through the use of the worksheet on Table 2, if farebox revenue for these categories becomes available.

2.2 Trackless Trolley Results

Calculation for the trackless trolley involved the use of the average fare data from the bus survey and the total farebox revenue from the trackless trolley system.

	Weekday	Saturday	Sunday	Total
A) Farebox Revenue				$642,620
B) $/Passenger[5]	0.2431	0.27	0.21	0.2442
C) $/Passenger-Mile[5]	0.1014	0.12	0.09	0.1028
D) Estimated System Passenger Trips (A ÷ B)				2,631,532
E) Estimated System Passenger-Miles (A ÷ C)				6,251,167

3.0 Survey Data Errors

The revenue-based method required the collection of data on 208 randomly selected trips. This is a considerable reduction over earlier methods. Due to errors in the collection of data on these trips however, less than 208 trips were recorded accurately enough for use in the estimation procedure. This memo addresses the extent and types of these errors.

---

[5]Obtained from Bus Survey, Table 1.

3.1 Type of Errors

Four main types of error have been distinguished here as follows:

I. The number of passengers boarding and alighting are not equal;
II. The mechanical failure of the farebox register;
III. The farebox register numbers were incorrectly recorded; and
IV. Missed Trips or Bus Breakdown.

I. Balance the Number of "Ons" and "Offs"

In many cases the number of passengers boarding and alighting did not balance. In some cases the cause of the discrepancy was evident. That is, where a large number of passengers were either boarding or alighting, it may have been difficult for the checker to keep track of the actual number of people involved. Other cases were less clear. It may be that passengers were already on board at the beginning or end of a trip. In some cases, a particular bus route may have been interlined with another route, or, for example, passengers may be boarding a bus on the inbound portion of a trip for an outbound journey. Passngers already on board or remaining on board were noted by the checkers in a few cases.

Of this category of error, 22 could be balanced with educated guessing, but seven remained unreconcilable.

II. Farebox Register Failure

Only two cases of farebox failure were reported by the checkers but this number may be larger in cases where the checker may not be aware of the failure. See Section III.

III. Incorrect Recording of Farebox Register Numbers

It is estimated that in a large number of cases the farebox register numbers were not accurately recorded. The reason for this is that in most cases the recorded farebox readings were too high giving high average fares of up to $3.00 per passenger. The total number of surveys in this category is eight. It may be that some of these cases are actually due to farebox failure, but these cannot be distinguished from the rest.

IV. Missed Trips or Bus Breakdown

There are eight surveys in this category of error.

There are recommended procedures[6] for the recovery of such missed trips so this category of error should not occur in any future surveys.

Other errors, such as the date or time not being on the survey sheet, are not significant to the requirements of this particular exercise.

3.2 Summary

Total Number of Ride Checks Commissioned	208
1. Irretrievable Errors	
Number of Passengers Unbalanced (I)	7
Farebox Register Failure (II)	2
Farebox Register Recorded Incorrectly (III)	8
Missed Trips or Bus Breakdown (IV)	8
Total Irretrievable Errors	25
2. Retrievable Errors	
Adjusted Passenger "ons" & "offs"	22
3. Balance - "Good" Surveys	161
4. Balance - including retrievable errors & surveys with no passenger trips	183

A list of the bus routes surveyed and their frequency is contained in the appendix, Table A1.

4.0 Confidence Interval and Precision

UMTA requires a confidence interval of 95 percent and a precision of +/- ten percent. Tests were performed on the average fare returned by the survey to assess if these specifications were met.

Sample Results

Sample Mean ($\bar{x}$) - 0.244
Sample Standard Deviation (s) - 0.137
Sample Variance (s^2) - 0.0188
Sample Size (n) - 183
Total Trip Population (N) - 3,936,946

Calculations

Sample to Population Ratio (f) = n/N = 0.000046482
Est. Population Variance (Var) = $(1-f)*(s^2/n)$ = 0.00010283

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[6]The previously-cited UMTA circular of December 19, 1983.

For a 95% Confidence Interval ..... $\bar{x} \pm 1.96 * \sqrt{VAR}$

$= 0.244 \pm 0.0198$

Precision = $\pm$ 8.14%

4.1 Hypothesis Test

Test the null hypothesis that the sample mean does not significantly differ from the population mean.

Sample Mean Revenue Per Trip ($\bar{x}$)	= $6.77
Total Trip Population	= 3,936,946
Total Revenue	= $24,815,317
System Average Revenue Per Trip (μ)	= $6.303

Equation

$t = (\bar{x} - \mu)/(\sqrt{s^2/n})$

$= (6.77 - 6.303)/0.54$

$= 0.865 < 1.96$, therefore accept the null hypothesis that the sample mean is not significantly different from the population mean at the 95% level.

Table A1
BUS ROUTES SURVEYED AND FREQUENCY

Route	Frequency	Route	Frequency
01	3	85	2
07	3	86	1
09	1	87	2
11	4	88	2
15	2	89	4
16	3	92	1
17	2	93	4
20	3	94	2
21	1	95	2
22	4	96	1
23	4	97	1
24	2	100	1
26	1	101	1
29	3	104	1
30	1	106	1
32	6	108	2
34	4	110	2
35	1	112	1
36	4	116	1
37	2	119	1
38	2	120	2
41	2	134	2
42	1	137	2
43	2	211	3
44	2	214	1
48	1	215	3
49	1	216	3
50	2	217	1
51	1	220	2
53	1	230	2
56	1	238	1
57	1	240	1
58	1	300	1
63	4	301	1
65	1	302	1
66	2	304	3
67	9	310	1
68	2	325	2
69	4	350	2
70	1	400	1
71	3	426	1
72	1	429	2
73	4	430	1
74	2	437	1
75	1	441	2
77	8	442	4
80	1	450	2
83	1	455	3
	116		84
Grand Total	200[1]		

[1]Excluding missed trips.

Table A2

DEFINITIONS

1. Passengers Boarded = Number of passengers who boarded and disembarked (including those with passes).

2. Passengers on Board = Number of passengers carried on board. The difference between 1 and 2 are those remaining on board on a looped route.

3. Bus Trip Distance = Total distance traveled by buses in sample.

4. Passenger Miles = Total miles traveled by all passengers in sample.

5. Trips in Sample = Number of trips in each sample period.

6. Total Revenue = Total revenue from each sample period.

7. Cumulative Average Farebox Revenue = Average farebox revenue taken from sample.

Sample Averages

8. Passengers Per Trip = Total number of passengers ÷ total number of trips.

9. Passenger Miles Per Trip = Total pass. miles ÷ total number of trips.

10. Revenue Per Trip = Total revenue ÷ number of trips.

11. Revenue Per Passenger = Total revenue ÷ number of passengers.

12. Revenue Per Passenger Mile = Total revenue ÷ total passenger miles.

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